AD-E300141

(12) LEVEL II

DNA 4248T

AD A058867

NUCOM/BREM:

An Improved HF Propagation Code for Ambient and Nuclear Stressed Ionospheric Environments

GTE Sylvania
189 "B" Street
Needham Heights, Massachusetts 02194

1 October 1976

Final Report for Period 19 April 1976 —30 September 1976

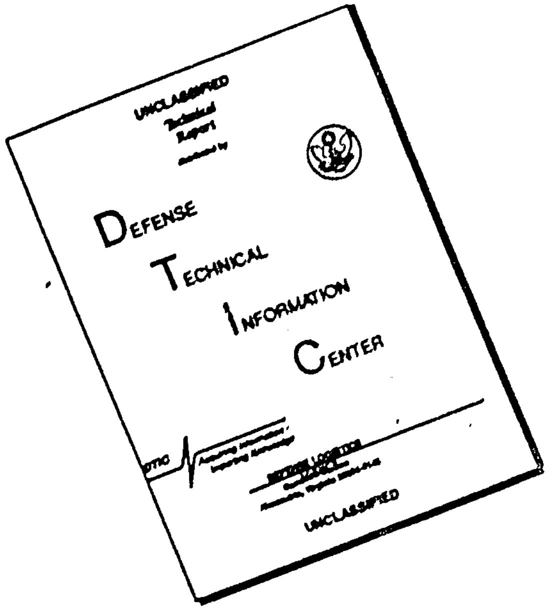
CONTRACT No. DNA 001-76-C-0261

THIS WORK SPONSORED BY THE DEFENSE NUCLEAR AGENCY
UNDER RDT&E RMSS CODE B322076464 S99QAXHB05303 H2590D.

Prepared for
Director
DEFENSE NUCLEAR AGENCY
Washington, D. C. 20305

Destroy this report when it is no longer needed. Do not return to sender.

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

(18) DNA, SBIE (19) 4248T, AD-E300 141

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER DNA 4248T	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) (6) NUCOM/BREM: An improved HF Propagation Code for Ambient and Nuclear Stressed Ionospheric Environments.		5. TYPE OF REPORT & PERIOD COVERED (9) Final Report, for Period 19 Apr 76—30 Sep 76,
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) (10) G. P. Nelson		8. CONTRACT OR GRANT NUMBER(s) (15) DNA 001-76-C-0261
9. PERFORMING ORGANIZATION NAME AND ADDRESS GTE Sylvania 189 "B" Street Needham, Massachusetts 02194		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS NWED Subtask S99QAXHB053-03
11. CONTROLLING OFFICE NAME AND ADDRESS Director Defense Nuclear Agency Washington, D.C. 20305		12. REPORT DATE (11) 1 October 1976
		13. NUMBER OF PAGES 262
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

62704H

Approved for public release; distribution unlimited.

(12) 260 p.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

(16) S99QAXH (17) B053

18. SUPPLEMENTARY NOTES

This work sponsored by the Defense Nuclear Agency under RDT&E RMSS Code B322076464 S99QAXHB05303 H2590D.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

HF
Radio Propagation
NUCOM II
Groundwave
Nuclear Effects
Ionospheric Propagation

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The NUCOM/BREM computer code extends the NUCOM II HF propagation code to include direct ray and groundwave propagation modes for airborne and ground-based communications links. Provision is made for user-supplied airborne antenna patterns for both vertical and horizontal polarizations, and for corrected horizontal noise-factors for airborne terminals. A variety of airborne antenna patterns are included and sample links are evaluated. This

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

407 418

20. ABSTRACT (Continued)

computer code greatly extends the usefulness of NUCOM II for the analysis of HF links employing airborne terminals and relay aircraft.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Continued)

LIST OF TABLES

SECTION 1.0

INTRODUCTION TO NUCOM/BREM

NUCOM II is a sophisticated and versatile HF communication prediction code for both ambient and nuclear stressed ionospheric environments [1,2]. However because NUCOM II considered only ionospherically propagated paths from ground-based terminals it could not be employed to predict the performance of groundwave and direct ray propagation between ground-based and elevated terminals. This limitation was particularly serious for the communication system analyst concerned with the performance of airborne HF assets in a nuclear environment.

A typical C^3 communications link employing an airborne terminal is shown in Figure 1-1. An HF link between an airborne command post and a ground entry point within radio line-of-sight is analyzed for nuclear induced propagation disturbances using both NUCOM II and NUCOM/BREM. Prior to the burst the dominant propagation mode found by each code is the 1E ionospheric skip mode which provides a received signal-to-noise ratio adequate for reliable communication. Five minutes after the detonation, however, the median signal-to-noise ratio predicted by NUCOM II is far below the acceptable threshold due to the high level of nuclear-induced nondeviative ionospheric absorption. The possibility that com-

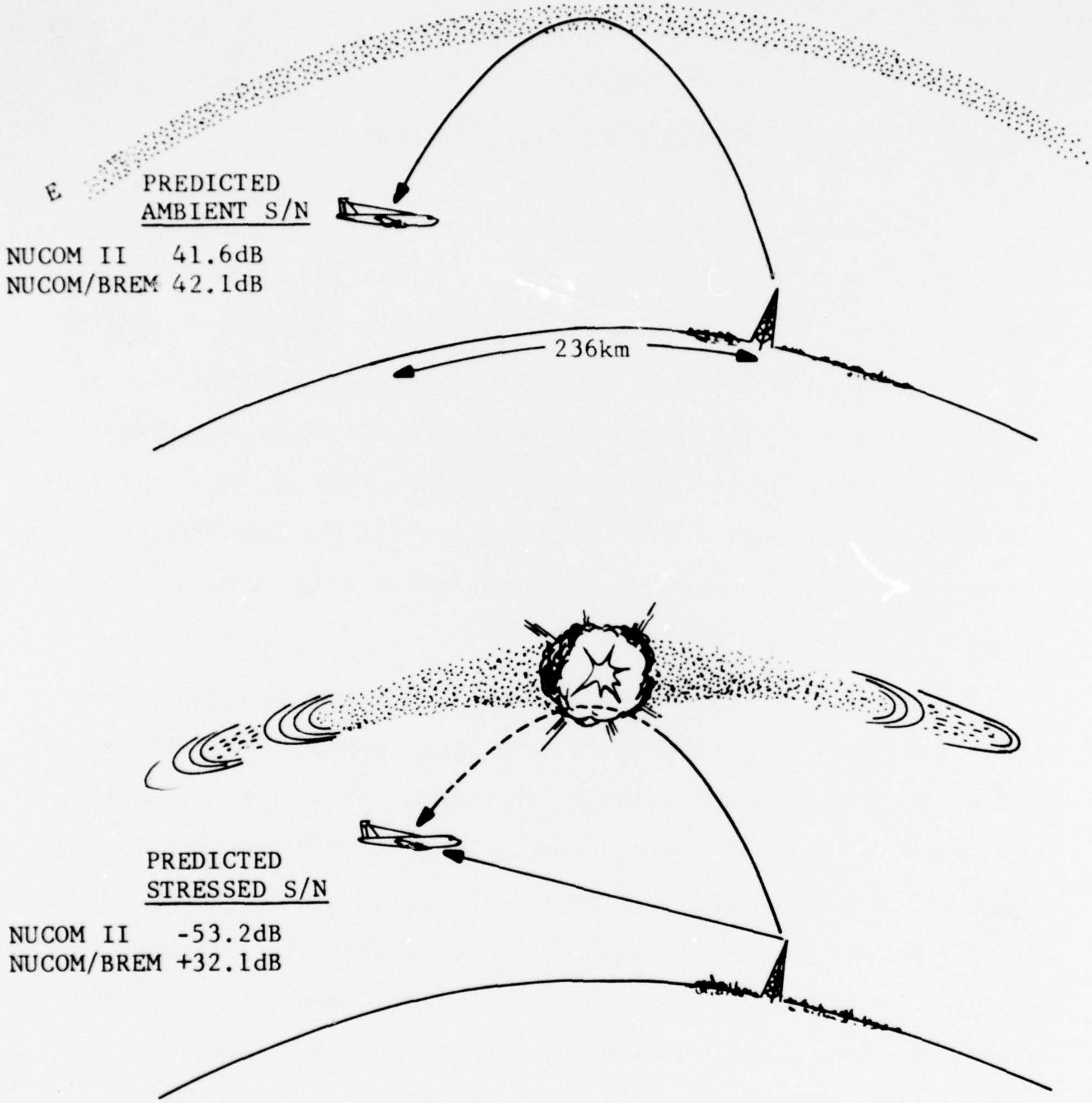


Figure 1-1. Comparison of Typical C^3 Links as Analyzed by NUCOM/BREM and NUCOM II

munication may continue through the post-attack environment via direct line-of-sight or extended groundwave modes is neglected by the unmodified NUCOM II code with the result that unduly pessimistic predictions of HF blackout result. This is especially important where elevated transmitters and/or receivers are concerned due to the substantial height gains which can provide extensive coverage using the groundwave mode. In fact the improved NUCOM/BREM code predicts that the direct signal ray path for the example will continue to support adequate HF communication in the absence of the ionospheric component as shown in Figure 1-1.

This neglect of nonionospheric propagation modes by the unmodified NUCOM II code and the resulting pessimistic predicted link performance for certain airborne assets in stressed environments is particularly troublesome in view of the critical importance of short distance air-to-ground airborne command post and TACAMO relay aircraft links in C^3 network analysis. Some typical types of C^3 circuits which cannot be analyzed by the unmodified NUCOM II code but are treated by NUCOM/BREM are illustrated in Figure 1-2.

The NUCOM/BREM propagation code described in this report extends the basic NUCOM II approach to include non-ionospheric HF propagation calculations for ground-to-ground, air-to-ground and air-to-air HF links. The groundwave and direct ray signal

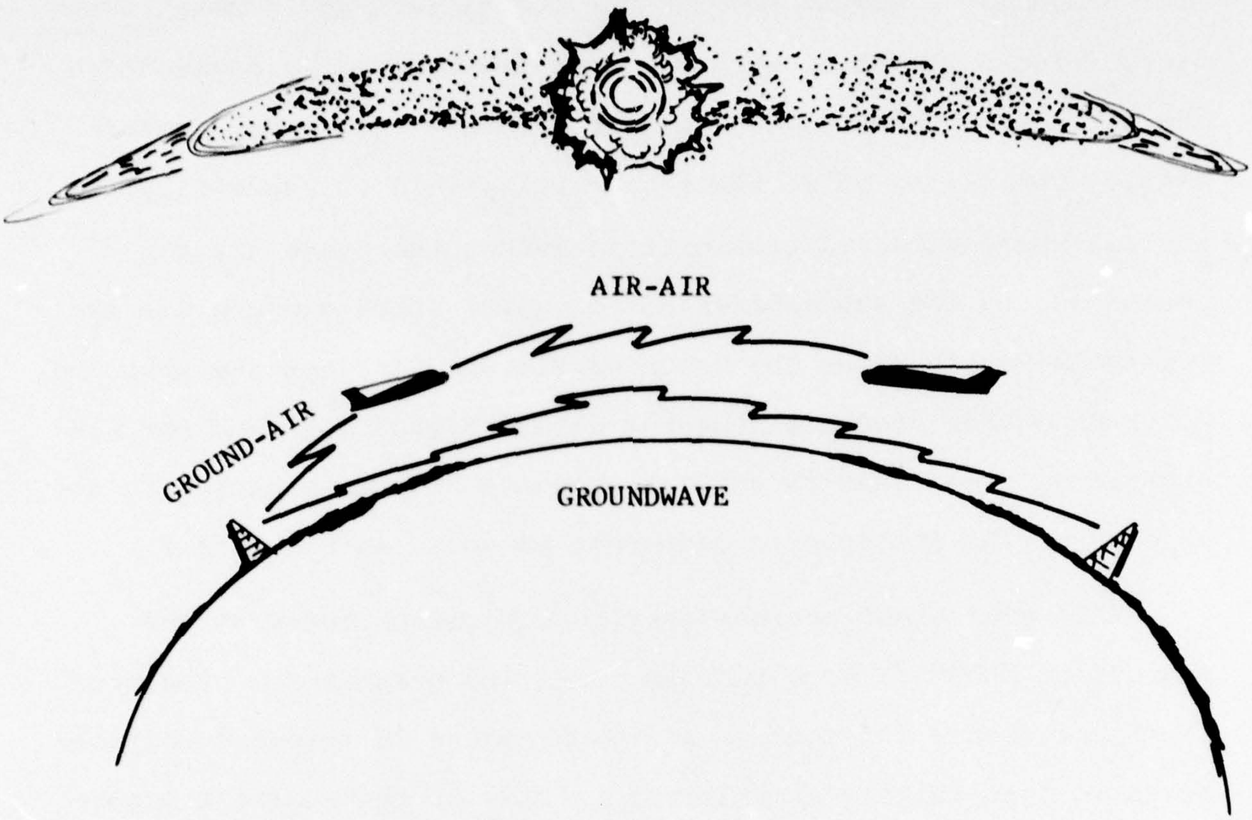


Figure 1-2. Types of C^3 radio links which cannot be analyzed by NUCOM II but are analyzed by NUCOM/BREM.

path field strengths are calculated with modified Bremmer[3] and van der Pol[4] equations independent of the normal ionospheric ray tracing calculations performed by the RAYTRACE subprogram of NUCOM II. The non-ionospheric HF signal paths are subsequently combined with the ionospheric ray paths in the COMEFF subprogram of NUCOM/BREM to yield a composite received signal power and an all mode signal-to-noise ratio. The overall computational architecture of NUCOM II and NUCOM/BREM is summarized in Figure 1-3. A more detailed description of the basic NUCOM II propagation code may be found in References 1 and 2.

Transmitting and receiving antenna gains may be either isotropic or arbitrary and specified in tabular format in both codes as provided by the user. The antenna vertical pattern input provisions for NUCOM II have been extended in NUCOM/BREM to also include negative radiation angles as required by elevated terminals. The input antenna pattern feature has been further modified to permit both horizontal and vertical polarization component pattern tables to be input independently. Direct ray and groundwave calculations are carried out separately for each polarization component in NUCOM/BREM since some elevated HF antennas may demonstrate strongly horizontal polarization patterns especially tail-to-fuselage wires, nose cap, and wing tip probes. Height gain functions for elevated terminals are calculated using

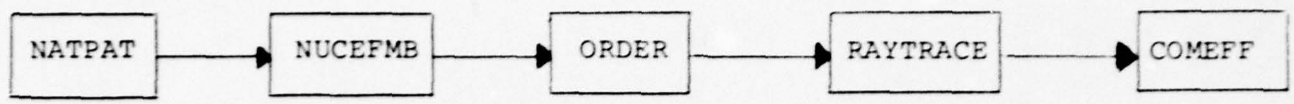


Figure 1-3. General Functional Program Architecture for NUCOM II and NUCOM/BREM

<u>NATPAT</u> - Calculates ambient ionospheric parameters control points along great circle path linking transmitter and receiver coordinates including atmospheric noise levels.

<u>NUCEFMB</u> - Calculates nuclear disturbances to ionospheric electron density vertical profiles.

<u>ORDER</u> - Orders nuclear-modified ionospheric profiles along the great circle circuit path between transmitter and receiver and includes shockwave effects (if present).

<u>RAYTRACE</u>- Calculates ionospheric ray paths through ambient and nuclear disturbed ionospheres and evaluates path losses for each ray path. Non-ionospheric ray path parameters are calculated in the NUCOM/BREM version.

<u>COMEFF</u> - Combines path loss and atmospheric noise level data from RAYTRACE with user input antenna and power information to calculate overall effects on received median signal-to-noise ratio.

modified Hankel functions of the first kind and order one-third [5].

The NUCOM/BREM code allows the user several options for the treatment of effective earth parameters for the calculation of groundwave field strengths. Effective ground conductivity and dielectric constants may be user input or automatically calculated from the ITS numerical world map data [6] in NUCOM/BREM. Two different methods of treatment for inhomogeneous ground paths are provided based upon the Suda [7] and Millington [8] techniques with the latter particularly suited for mixed land-sea signal paths.

A somewhat novel feature of NUCOM/BREM permits the user to assess the effects of sea state parameters on the apparent conductivity of the ocean surface for long distance groundwave signal paths. The condition of the sea surface along a groundwave path may be described by a user supplied average wind velocity which is used to compute the effective sea surface conductivity in the fashion of Barrick [9] and Kaliszewski [10].

Provision is also made in the NUCOM/BREM code for the inclusion of a user-specified horizontally polarized HF noise-height compensation factor to provide appropriate atmospheric noise level values for predominantly horizontally polarized airborne HF antennas.

The final output of the NUCOM/BREM code is the all-mode median received signal-to-noise ratio, P_{TA}, given by

$$P_{TA} = 10 \; Log_{10} \left\{ \frac{P_{TI} + P_{TV} + P_{TH}}{P_{NV} + P_{NH}} \right\} \; dBW \qquad (1-1)$$

where

P_{TI} is the total received ionospheric signal power density,

P_{TH} is the total received non-ionospheric signal power density polarized in the horizontal plane,

P_{TV} is the total received non-ionospheric signal power density polarized in the vertical plane,

P_{NV} is the received atmospheric noise density in the vertical plane and

P_{NH} is the received atmospheric noise density in the horizontal plane.

This report details the modifications to NUCOM II to incorporate these features and discusses the applicability and limitations of the non-ionospheric propagation calculations. Sample calculations are presented and discussed for typical link geometries and examples of airborne HF antenna patterns are provided for the guidance of the user.

NUCOM/BREM is coded in IBM FORTRAN IV G for the IBM System 370/145.

REFERENCES

1. Documentation of NUCOM II - An Updated HF Nuclear Effects Code, D. L. Nielson, Editor. DNA Report 3108F1, Parts I and II, April 1973.
2. NUCOM II Code: User's Guide, E. J. Feniger, MEECN Nuclear Effects System Codes, Volume 10, G. E. Tempo, GE75-TMP-0, June 1975.
3. Terrestrial Radio Waves, H. Bremmer, Elseview Publishing Co., New York, 1949.
4. The Diffraction of Electro-magnetic Waves from an Electrical Point Source Round a Finitely Conducting Sphere, With Applications to Radio Telegraphy and the Theory of the Rainbow, B. van der Pol and H. Bremmer, Phil. Mag., Vol. 24, p. 141, July 1937, p. 825; Supplement, November, 1937; Vol. 25, p. 816, June 1938; Vol. 27, p. 261, March 1939.
5. Reference Tables of the Modified Hankel Functions of Order One - Third and Their Derivatives, Staff of the Computation Laboratory, Harvard University Publication, 1945.
6. Predicting Long-Term Operational Parameters of High-Frequency Sky-Wave Telecommunications Systems, A. F. Barghausen, et al. ESSA Technical Report ERL-110-ITS-78, May 1969 and Addendum I, December 1970.
7. Field Strength Calculation, K. Suda, Wireless Engineer, Vol. 47, September 1956, pp. 249-251.
8. Groundwave Propagation Over an Inhomogeneous Smooth Earth, G. Millington, PIEE, 96, 1949, pp. 53-64.
9. Theory of HF and VHF Propagation Across the Rough Sea, Parts I and II, D. Barrick, Radio Science, 6(5), pp. 517-533, 1971.

REFERENCES.....CONT'D.

10. Modification and Extension of the CCIR Groundwave Prediction Program for Rough Sea Paths, T. Kaliszewski. 1976 International IEEE/AP-S Symposium and USNC/URSI Meeting, (Paper No. F5(9)), October 1976, Amherst, MA.

SECTION 2.0

DESCRIPTION OF ANALYTIC APPROACH

2.1 Calculation of Uncompensated Field Strength

The NUCOM II subprogram RAYTRACE calculates an effective path loss for each ionospheric ray and incorporates this path loss figure into a power flux summation expression in COMEFF which gives the total received ionospheric signal power density for all propagating rays on the circuit, P_{TI}, as follows:

$$P_{TI} = \sum_{i=1}^{n} \frac{P_o (GT_i)(GR_i)C^2}{4\pi \mathrm{alog}_{10}(Li/10) * f^2 * 10^{12}} \quad \text{(Watts)} \qquad (1-2)$$

where

P_o = transmitter power density in W/Hz

GT_i = power gain of transmitting antenna at θ and $\emptyset$ in question, relative to isotropic

GR_i = power gain of receiving antenna at θ and $\emptyset$ in question, relative to isotropic

Li = path loss for i-th ray including free space loss, ground reflection, deviative and nondeviative absorption and defocussing losses

c = velocity of light

f = frequency in MHz

n = number of found ionospheric rays, and

$\emptyset,\theta$ = elevation and azimuth angles respectively.

Because of reciprocity we may categorize all non-ionospheric paths in the present application as consisting of one or more of the following computational types:

a. Direct Ray (line-of-sight)

b. Groundwave, and

c. Reflected Ray.

The analytic approach of the Bremmer-van der Pol computational algorithms makes expression of the nonionospheric components in the formulation of Equation (1-2) somewhat awkward however. Instead we shall first calculate the groundwave and direct ray electric field strengths at the receiver assuming that radiation occurs from an optimally oriented elementary electric dipole radiating the ideal one kilowatt effective power as defined by Bremmer [(3)]. The resulting value of received field strength will then be compensated for user specified antenna gains and actual transmitted power density to yield a value of received power which can then be directly combined with the ionospheric ray power flux summation in COMEFF to yield the all mode expression shown in Equation 1-1. This process is repeated for each polarization component and the term <u>uncompensated received field</u> will be used to refer to the calculated basic Bremmer-van der Pol received electric field value <u>before</u> adjustment for actual transmitter powers and antenna gains. This approach has the additional advantage of readily permitting compari-

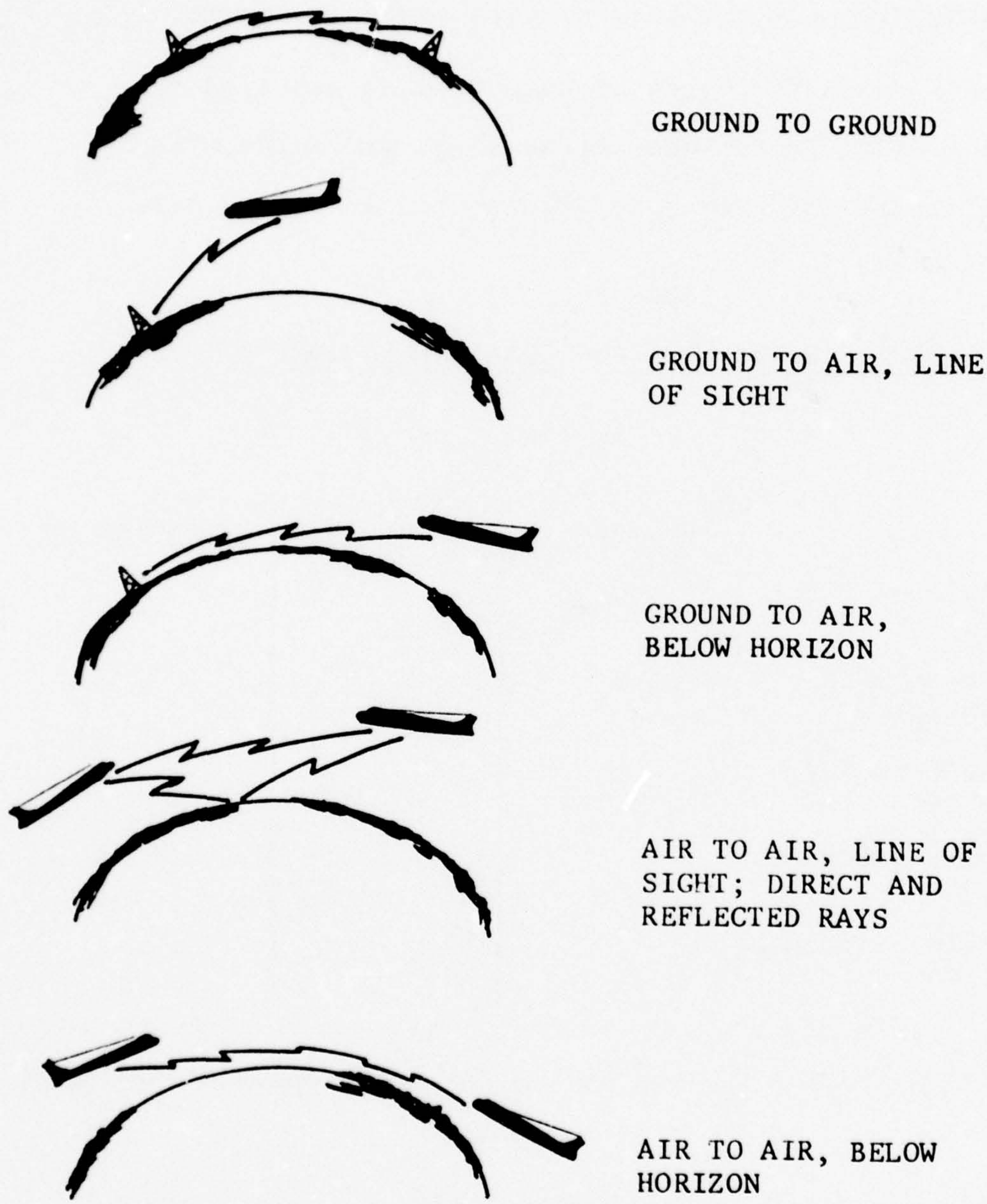


Figure 2-1 Types of Nonionospheric Computational Geometry

son of results with the tabulated values given by Bremmer [3].

Table 2-1 shows the types of computations required for each of the five different geometries which may exist with airborne terminals and which are illustrated in Figure 2-1.

TABLE 2-1

TYPES OF NON-SKY WAVE COMPUTATIONAL GEOMETRY

	Groundwave	Direct Ray	Reflected Way
Both terminals on ground	X		
One airborne terminal line of sight	X		
One airborne terminal, beyond horizon	X		
Both terminals airborne, line of sight		X	X
Both terminals airborne, beyond horizon	X		

In the following sections we discuss each computational type in turn.

2.1.1 Groundwave Field Strength Calculation

This computation employs the Bremmer-van der Pol equations with height gain evaluation using modified Hankel functions of

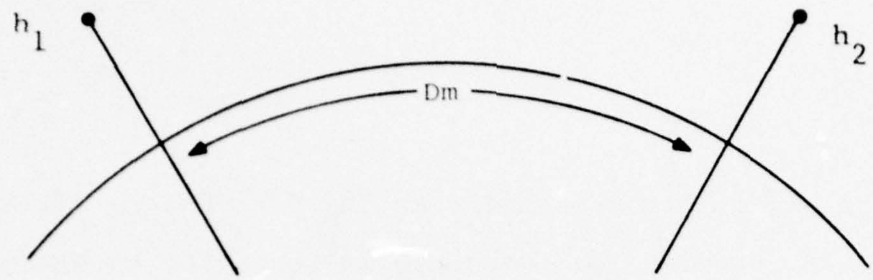


Figure 2-2 (a) Definition of variables in groundwave calculation.

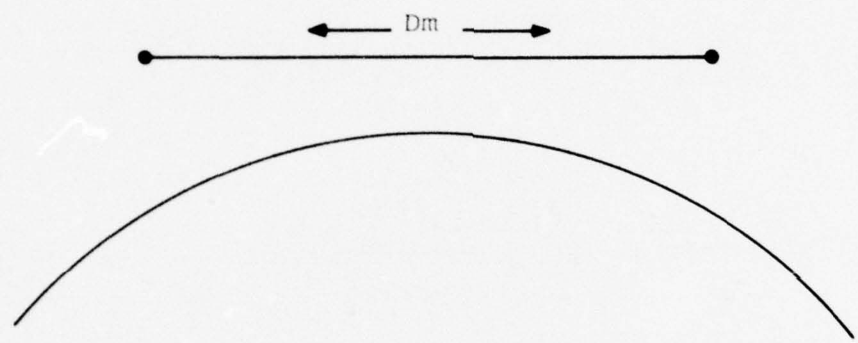


Figure 2-2 (b) Definition of variables used in direct ray analysis.

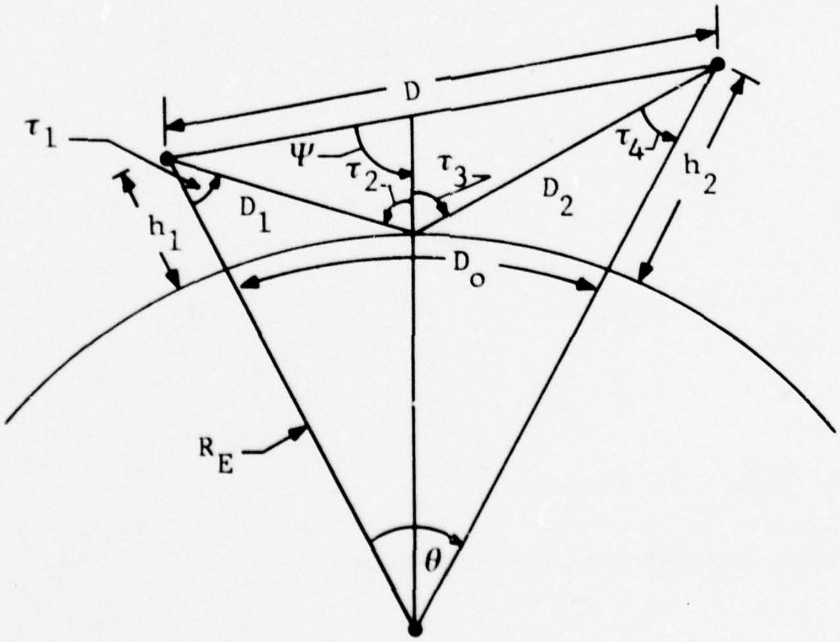


Figure 2-2 (c) Definition of variables used in reflected ray analysis.

the first kind and order one-third. As shown in Figure 2-2(a), for the standard one-kW transmitted ERP as specified by Bremmer and a short optimally oriented dipole of appropriate polarization orientation the uncompensated rms field strength ($\mu V/m$) as given by Bremmer (op. cit.) is:

$$E = \frac{752.0}{D_m} \sqrt{\chi} \left| \sum_{s=0}^{\infty} f_s(h_1) f_s(h_2) \frac{e^{i\tau_s \chi}}{2\tau_s - 1/\delta_e^2} \right| \ \mu V/m \tag{2-1}$$

$$K_e = 0.002924\, \lambda_m^{1/3} \frac{\sqrt{\sqrt{\varepsilon^2 + 36 \cdot 10^{24}\, \sigma_e^2 \lambda_m^2}}}{\sqrt[4]{(\varepsilon - 1)^2 + 36 \cdot 10^{24}\, \sigma_e^2\, \lambda_m^2}} \tag{2-2}$$

$$\psi_e = \arctan\left(\frac{\varepsilon}{6.10^{12} \sigma_e \lambda_m}\right) - \frac{1}{2} \arctan\left(\frac{\varepsilon - 1}{6.10^{12} \sigma_e \lambda_m}\right) \tag{2-3}$$

$$\chi = 53.7 \frac{D_m}{\lambda_m^{1/3}} \tag{2-4}$$

$$\delta_e = K_e e^{i(135^\circ - \psi_e)} \tag{2-5}$$

D_m = distance in meters

ε = dielectric constant (relative)

σ_e = conductivity, e.m.u. units

λ_m = wavelength in meters

h_i = transmitter height in meters

h_2 = receiver height in meters

The values of τ_s follow from ($\tau_s = \mathrm{Re}\,\tau_s + i\mathrm{Im}\,\tau_s$)

(a) K_e small:

$$\begin{aligned}
\mathrm{Im}\,\tau_o &= 1.607 - K_e \sin(45^o + \psi_e) - 1.237\, K_e^3 \sin(75^o + 3\psi_e) + \\
&\quad + \tfrac{1}{2} K_e^4 \sin(4\psi_e) - 2.755\, K_e^5 \sin(75^o - 5\psi_e) \ldots \\
\mathrm{Im}\,\tau_1 &= 2.810 - K_e \sin(45^o + \psi_e) - 2.163\, K_2^3 \sin(75^o + 3\psi_e) + \\
&\quad + \tfrac{1}{2} K_e^4 \sin(4\psi_e) - 8.422\, K_e^5 \sin(75^o - 5\psi_e) \ldots \\
\mathrm{Im}\,\tau_2 &= 3.795 - K_e \sin(45^o + \psi_e) - 2.921\, K_e^3 \sin(75^o + 3\psi_e) + \\
&\quad + \tfrac{1}{2} K_e^4 \sin(4\,\psi_e) - 15.36\, K_e^5 \sin(75^o - 5\psi_e) \ldots
\end{aligned} \qquad (2\text{-}6)$$

$$\mathrm{Im}\,\tau_s \sim 1.932(s + 3/4)^{2/3} - K_e \sin(45^o + \psi_e) \ldots \quad (s > 2)$$

$$\mathrm{Re}\,\tau_o = 0.928 + K_e\cos(45^\circ + \psi_e) + 1.237\,K_e^3\cos(75^\circ + 3\psi_e) -$$

$$- \frac{1}{2}K_e^4\cos(4\psi_e) - 2.775\,K_e^5\cos(75^\circ - 5\psi_e)\cdots$$

$$\mathrm{Re}\,\tau_1 = 1.622 + K_e\cos(45^\circ + \psi_e) + 2.163K_e^3\cos(75^\circ + 3\psi_e) -$$

$$- \frac{1}{2}K_e^4\cos(4\psi_e) - 8.422\,K_e^5\cos(75^\circ - 5\psi_e)\cdots \tag{2-6}$$

$$\mathrm{Re}\,\tau_2 = 2.191 + K_e\cos(45^\circ + \psi_e) + 2.921\,K_e^3\cos(75^\circ + 3\psi_e) -$$

$$- \frac{1}{2}K_e^4\cos(4\psi_e) - 15.36\,K_e^5\cos(75^\circ - 5\psi_e)\ldots$$

$$\mathrm{Re}\,\tau_s \sim 1.116(s + 3/4)^{2/3} + K_e\cos(45^\circ + \psi_e)\ \ldots\ (s > 2)$$

(b) K_e large:

$$\mathrm{Im}\,\tau_o = 0.7003 - 0.6183\,\frac{\sin(15^\circ - \psi_e)}{K_e} + 0.2364\,\frac{\cos(2\psi_e)}{K_e^2} -$$

$$- 0.0533\,\frac{\sin(15^\circ + 3\psi_e)}{K_e^3} - 0.00226\,\frac{\sin(60^\circ - 4\psi_e)}{K_e^4}\cdots$$

$$\mathrm{Im}\,\tau_1 = 2.232 - 0.1940\,\frac{\sin(15^\circ - \psi_e)}{K_e} + 0.0073\,\frac{\cos(2\psi_e)}{K_e^2} +$$

$$+ 0.0120\,\frac{\sin(15^\circ + 3\psi_e)}{K_e^3} + 0.00160\,\frac{\sin(60^\circ - 4\psi_e)}{K_e^4}\cdots$$

$$\mathrm{Im}\,\tau_s \sim 1.932\,(s + 1/4)^{2/3} - \frac{0.2241}{(s + 1/4)^{2/3}}\,\frac{\sin(15^\circ - \psi_e)}{K_e}\ldots\ (s > 1)$$

$$\mathrm{Re}\,\tau_0 = 0.4043 + 0.618\,\frac{\cos(15^\circ - \psi_e)}{K_e} - 0.236\,\frac{\sin(2\,\psi_e)}{K_e^2} - \qquad (2\text{-}7)$$

$$- 0.0533\,\frac{\cos(15^\circ + 3\psi_e)}{K_e^3} + 0.00226\,\frac{\cos(60^\circ - 4\psi_e)}{K_e^4} \cdots$$

$$\mathrm{Re}\,\tau_1 = 1.288 + 0.194\,\frac{\cos(15^\circ - \psi_e)}{K_e} - 0.0073\,\frac{\sin(2\,\psi_e)}{K_e^2} +$$

$$+ 0.0120\,\frac{\cos(15^\circ + 3\psi_e)}{K_e^3} - 0.00160\,\frac{\cos(60^\circ - 4\,\psi_e)}{K_e^4} \cdots$$

$$\mathrm{Re}\,\tau_s \sim 1.116(s + 1/4)^{2/3} + \frac{0.2241}{(s + 1/4)^{2/3}}\,\frac{\cos(15^\circ - \psi_e)}{K_e} \cdots (s > 1)$$

The height gain factor $f_s(h_1)$ is computed from

$$f_s(h_1) = \sqrt{\frac{\chi_1^2 - 2\,\tau_s}{-\,2\tau_s}}\;\frac{H_{1/3}^{(1)}\,\{\frac{1}{3}\,(\chi_1^2 - 2\,\tau_s)^{3/2}\}}{H_{1/3}^{(1)}\,\{\frac{1}{3}\,(-\,2\tau_s)^{3/2}\}} \qquad (2\text{-}8)$$

(for the value of $H_{1/3}$, see Appendix C; $\mathrm{Im}(\chi_1^2 - 2\,\tau_s) < 0$

and $\mathrm{Im}(-\,2\,\tau_s) > 0$)

in which

$$\chi_1^2 = 0.03674\,\frac{h_1 m}{\lambda_m^{2/3}} \qquad (2\text{-}9)$$

or as follows when $|\delta| << 1$:

(a) approximately $h_{1\,m} > 60\lambda_m^{2/3}$:

$$f_s(h_1) = e^{-i\pi/4 + \frac{i}{3}(\chi_1^2 - 2\tau_s)^{3/2}} \{1 - i\frac{0.2083}{(\chi_1^2 - 2\tau_s)^{3/2}} - \frac{0.3342}{(\chi_1^2 - 2\tau_s)^3} \ldots\} -$$

$$A_s \frac{-e^{i\pi/4 - \frac{i}{3}(\chi_1^2 - 2\tau_s)^{3/2}} \{1 + i\frac{0.2083}{(\chi_1^2 - 2\tau_s)^{3/2}}\}}{\delta_e \sqrt[4]{\chi_1^2 - 2\tau_s}} \qquad (2\text{-}10)$$

$(-45^\circ < \arg \sqrt[4]{\ } < 0)$

$A_o = 0.3582\ e^{i120^\circ}$; $\qquad A_1 = 0.3129\ e^{-i60^\circ}$

$A_2 = 0.2903\ e^{i120^\circ}$ $\qquad A_3 = 0.2760\ e^{-i60^\circ}$

$$A_s = 0.3440 \frac{(-1)^{s+1}}{(s + 3/4)^{1/6}} e^{-i\pi/3} \qquad (s > 3) \qquad (2\text{-}11)$$

(b) approximately $h_{1\,m} < 60\lambda_m^{2/3}$:

$$f_s(h_1) = 1 + 6.283(\frac{1}{x^{1/3}\delta_e} - \frac{1}{x})\frac{h_1}{\lambda} - 39.48 \frac{(1 - x^{2/3}\delta_\varepsilon\tau_s)}{x^{4/3}\delta_e}(\frac{h_1}{\lambda})^2 \ldots,$$

in which

$$x = \frac{4.10^7}{\lambda_m}. \qquad (2\text{-}12)$$

The second height-gain factor is computed in the same way except that h_1 is replaced by h_2. The same formula apply to the horizontal dipole, δ_e being replaced by δ_m where

$$\delta_m = K_m e^{i(45^\circ + \psi_m)} \quad . \tag{2-13}$$

These expressions thus provide the uncompensated field strength at the receiver for each polarization mode. The received power density is then obtained by compensating the results of the above calculations for user specified antenna gains and actual power density as described in Section 2.3.

2.1.2 Direct Ray Calculation

The power flux due to an isotropic radiator at a distance d is given by:

$$P_F = \frac{P_T}{4\pi d^2} \quad \text{Watts/meter}^2 \tag{2-14}$$

when d is expressed in meters, and P_T is the total radiated power in Watts. The power gain of a short maximally oriented dipole relative to isotropic is 1.5 which gives a flux at the receiver of

$$P_F = \frac{1.5\ P_T}{4\pi d^2} \quad \text{Watts/meter}^2 \tag{2-15}$$

Equating this expression to power flux in terms of rms field strength and rearranging yields

$$E = \left[\frac{1.5\,\eta_o\,P_T}{4\pi d^2\sqrt{2}}\right]^{1/2} \quad \text{Volts/meter} \tag{2-16}$$

where η_o is the characteristic impedance of free space ($\approx 120\pi$). For the standard 1 kW ERP of Bremmer (op. cit.) this reduces to

$$E = \frac{1.50 * 10^5}{d} \quad \mu v/m \tag{2-17}$$

where d is expressed in kilometers. This is the direct ray field strength at a distance D from a 1 kW ERP transmitter using a short optimally oriented dipole remote from ground. Note that the same expressions may be employed to predict both horizontal and vertical polarization components.

This expression is employed to evaluate the line-of-sight direct ray between airborne terminals as shown in Figure 2-2(b). The ground reflected component is evaluated separately as described in 2.1.3.

2.1.3 Reflected Ray Calculations

A line-of-sight signal path between elevated terminals may be decomposed into a direct and a reflected ray for each polarization type. The direct ray is subject only to free space transmission loss as discussed in Section 2.1.2.

The reflected ray losses may be considered to result from three sources: free space loss over the total path length, the

Fresnel reflection loss at the surface, and the defocusing or divergence loss at reflection due to the convex shape of the assumed perfectly spherical surface of the earth. For the standard 1 kW ERP of Bremmer and an optimally oriented dipole the received reflected field strength as shown in Figure 2-2(c) is given by Bremmer[3] as:

$$E = \frac{150}{D} \left| \alpha \frac{D}{(D_1 + D_2)} R(\tau_2) e^{2\pi i \frac{\Delta}{\lambda}} \right| \mu V/m \tag{2-18}$$

$$\alpha = \frac{R_e (D_1 + D_2) \sqrt{\sin \tau_2 \cos \tau_2}}{\sqrt{b \cdot \gamma \cdot \theta (D_1 \gamma \cos \tau_4 + D_2 b \cos \tau_1)}} \tag{2-19}$$

where τ_1, τ_2, τ_4, D_1, and D_2 are as defined in Figure 2-2(c) and

$a = R_e$ (or equivalent earth radius)

$b = R_e + h_t$

$\gamma = R_e + h_r$

in which

$$R(\tau_2) = \begin{cases} \dfrac{\mu^2\cos\tau_2 - \sqrt{\mu^2 - \sin^2\tau_2}}{\mu^2\cos\tau - \sqrt{\mu^2 - \sin^2\tau_2}}, & \text{(vertical dipole)} \\ \\ \dfrac{\cos\tau_2 - \sqrt{\mu^2 - \sin^2\tau_2}}{\cos\tau_2 + \sqrt{\mu^2 - \sin^2\tau_2}}, & \text{(horizontal dipole)} \end{cases} \tag{2-20}$$

$$\mu^2 = \sqrt{\varepsilon^2 + 36\cdot 10^{24}\,\sigma_e^2\lambda_m^2}\; e^{\,i\,\arctan(6\cdot 10^{12}\sigma_e\lambda_m/\varepsilon)},$$

or, for $\tau_2 \sim \pi/2$:

$$R(\tau_2) = -1 - 2\,ix^{1/3}\,\delta\cos\tau_2 + 2x^{2/3}\,\delta^2\cos^2\tau_2 \ldots \tag{2-21}$$

$$\left(x = \frac{4\cdot 10^7}{\lambda_m}\;;\; \delta = \delta_e,\ \delta_m \text{ resp.}\right)$$

τ_2, D_1, D_2 and Δ are to be determined in succession from

$$\tan\tau_2 = \frac{D_o}{(h_1 + h_2)} + \frac{D_o\text{ km}}{6366}\,\frac{(h_1^2 + h_2^2)}{(h_1 + h_2)^2}\left\{1 + \frac{D_o^2}{2(h_1+h_2)^2}\right\}\ldots, \tag{2-22}$$

(D_o, distance measured along the earth's surface between the projections of the transmitter and the receiver)

$$\cos\tau_1 \sim \sqrt{\cos^2\tau_2 + 3.142\cdot10^{-7}\sin^2\tau_2\, h_1 m}\ ,$$

$$\cos\tau_4 \sim \sqrt{\cos^2\tau_2 + 3.142\cdot10^{-7}\sin^2\tau_2\, h_2 m}\ , \tag{2-22}$$

$$D_1\ \mathrm{km} \sim 6366(\cos\tau_1 - \cos\tau_2) + 0.001\cos\tau_1 h_1 m\ ,$$

$$D_2\ \mathrm{km} \sim 6366(\cos\tau_4 - \cos\tau_2) + 0.001\cos\tau_4 h_2 m\ , \tag{2-23}$$

$$\cot\psi = \frac{(D_2 - D_1)}{(D_2 + D_1)}\cot\tau_2, \tag{2-24}$$

$$\Delta = \left(\frac{\sin_{\psi}}{\sin\ _2} - 1\right) D \tag{2-25}$$

and $R_E = 6366$ km.

2.2 Calculation of Effective Ground Parameters

The conductivity σ and dielectric constant ε on the surface of the earth determine not only the reflection coefficient for an HF signal reflected from the ground surface but also the rate of attenuation of a groundwave signal with distance. For a perfectly homogeneous spherical earth the groundwave predictive techniques of Bremmer and van der Pol provide excellent solutions. Except possibly for paths along smooth sea surfaces, however, real signal paths are usually inhomogeneous. The complete solution for groundwave propagation along an inhomogeneous unsmooth path whose ground parameters may vary with distance requires extensive numerical integration of the Volterra equations as well as a detailed description of both the ground parameters and vertical terrain profiles along the entire path [1,2]. Since few, if any, paths can be so completely specified, a variety of approximation techniques have been developed and tested against real measurements by various authors in an attempt to simplify the prediction of groundwave signal strengths over inhomogeneous paths. Both the Millington (op.cit.) and Suda(op. cit.) techniques have been extensively applied to practical broadcasting problems for many years and usually provide reasonable agreement with measurements. The reader is referred to Sections 2.2.2 and 2.2.3 and to the original papers by these authors for further details.

Depending upon the particular groundwave path to be analyzed by NUCOM/BREM the user has several options insofar as inhomogeneous groundwave analysis is concerned within the scope of the Suda and

Millington techniques. Generally speaking the Suda technique should provide more realistic predictions when the variations in surface parameters are relatively gradual along the path whereas the Millington approach is more suitable for sharp transitions such as mixed land-sea paths. The user is urged to compare the results of both techniques in questionable cases and to interpret the results for complex inhomogeneous paths with some care.

One particular type of inhomogeneous path geometry which deserves special comment is that featuring a sharp land-to-sea boundary. From the earliest days of radio research it has been known that transmission and reception at coastal stations sited near the sea often differs markedly from that at nearby sites further inland from the beach. Two types of anomalous behavior are commonly observed near land-sea interfaces: distorted direction finding behavior and anomalous variations of signal amplitude. While the rather misleading term "coastal refraction" continues to be used to describe these coastal effects, the work of Grunberg (3), Millington (4), Wait (5) and others (6,7) has shown both analytically and experimentally that these coastal phenomena must be described in terms of diffraction-like interface boundary effects. The "anomalous" amplitude variations near land-sea interfaces are generally termed "recovery effects" and are beyond the scope of the present analysis. Complete prediction of the HF field strength behavior near a land-sea boundary requires detailed description of the subsurface interface geometry as has been shown by Wait and Spies (8) although Millington (4) and others (9,10) have shown experimentally that the "Millington Technique" yields good results in areas away from the

interface region. It is suggested that calculations made by NUCOM/BREM employing the Millington technique (see Section 2.2.3) should be considered as possibly suspect within 100λ of the interface due to these boundary effects.

The groundwave calculation subroutines in NUCOM/BREM assume a homogeneous earth surface and require as input both conductivity σ and relative dielectric constant ε. NUCOM/BREM permits use of either a user specified set of ground constants or the calculation of effective mean homogeneous ground constants for nonionospheric paths from the ITS numerical map data in NUCOM/BREM using the method of Suda (op.cit.). Furthermore the user has the option of either a homogeneous path solution or an approximate inhomogeneous solution employing the method of Millington.

NUCOM II and NUCOM/BREM require ground constant data to calculate the Fresnel ground reflection loss coefficients in RAYTRACE as part of the determination of total ray path loss for ionospheric rays as well as for groundwave calculations of path loss. Figure 2-3 shows the program flow for the NUCOM II and NUCOM/BREM ground reflection calculations. NATPAT reads the ITS "Blue Binary" world ground numerical map (11) from logical unit 1 and transfers the coefficients to logical unit 4 for later use by RAYTRACE. These world map coefficients have been produced from geographical world maps of ground constants using the well-known spherical harmonic techniques of Jones and Gallet (12).

When RAYTRACE needs to calculate the ground loss at a geographical particular point on the surface of the earth it passes the geographical coordinates, frequency, and ray arrival angle to the

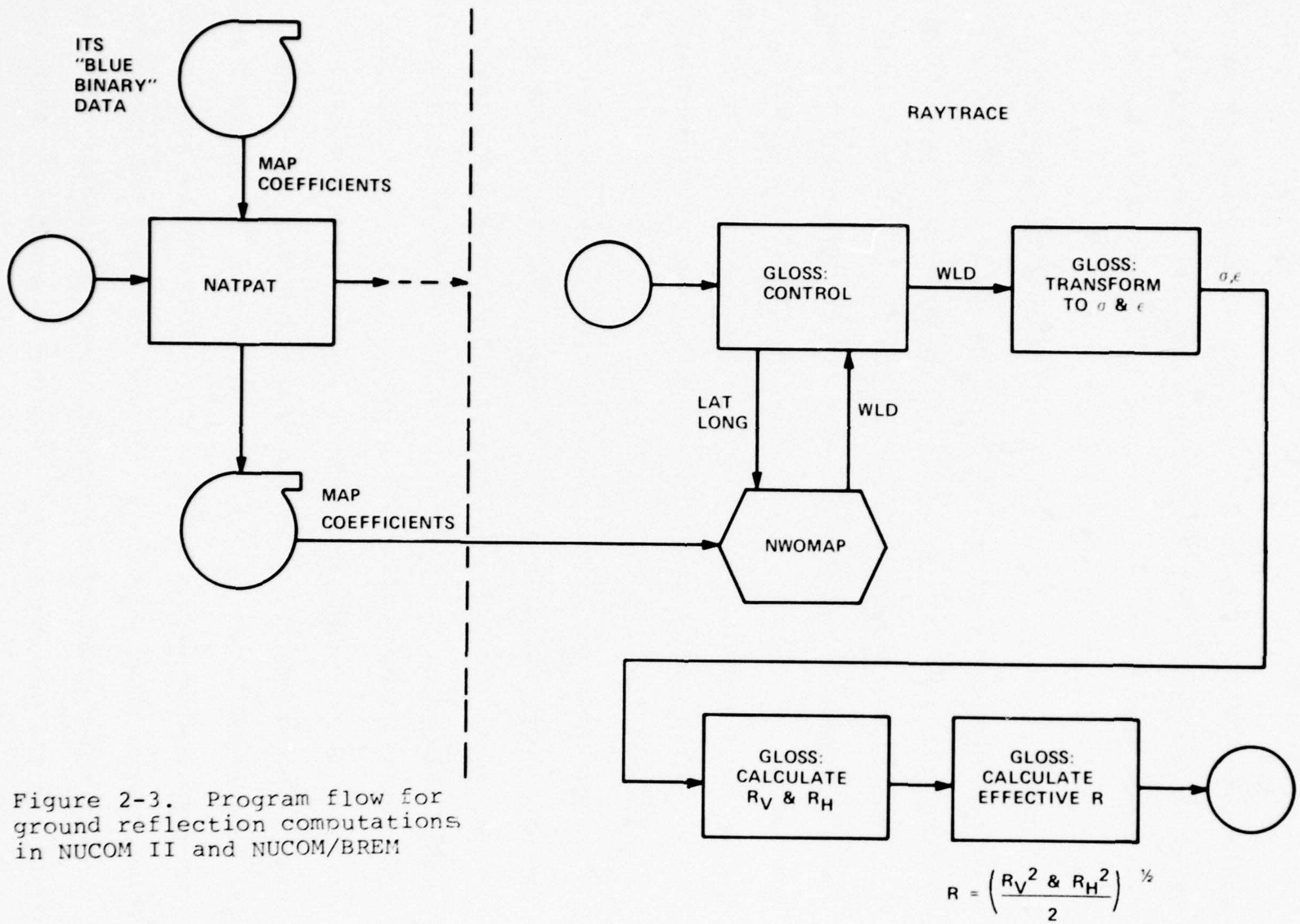


Figure 2-3. Program flow for ground reflection computations in NUCOM II and NUCOM/BREM

subroutine GLOSS. GLOSS, in turn, passes the geographical coordinates to the subroutine NWOMAP which applies the inverse mapping transformation to the coefficients read from unit 4 and returns a dimensionless variable WLD to GLOSS.

Using the conversion factors described in Section 2.2.1 GLOSS then converts the returned value of WLD to a conductivity and dielectric constant for the point in question as shown in Figure 2-3.

The subroutine GLOSS then applies the ordinary Fresnel reflection equations to the ground constants so determined to yield the horizontal and vertical reflection coefficients, R_H and R_V, whose RMS value is taken as the effective average reflection coefficient for a randomly polarized skywave approaching the ground at the point in question.

NUCOM/BREM determines the effective ground parameters needed for groundwave calculations as follows. The user first specifies whether he is providing his own effective ground constants or wishes them to be automatically calculated from the ITS world map data available on unit 4 from NATPAT. He further specifies whether the path is to be considered homogeneous or heterogeneous. If the user is providing the effective constants they are directly employed for the analysis and computation proceeds as in Figure 2-4(a). If the user wishes to use map data for a homogeneous path calculation the program calls NWOMAP to evaluate the numerical coefficients at each of the n points whose geographical coordinates have been defined by the particular path geometry in question. After conversion of the map variable values to ground parameters the effective mean

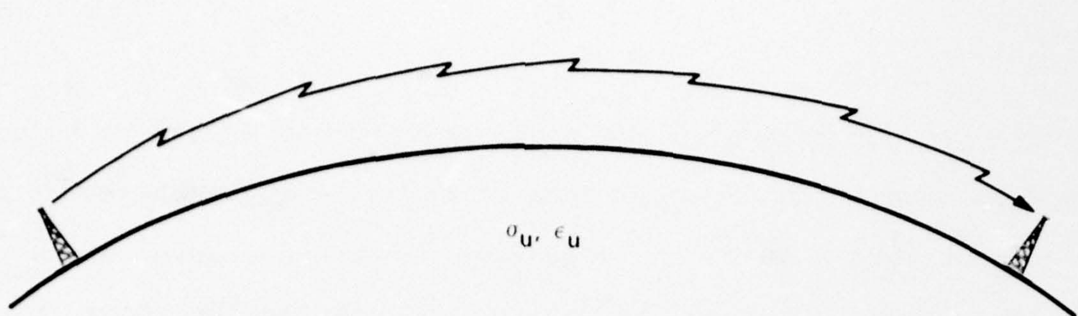
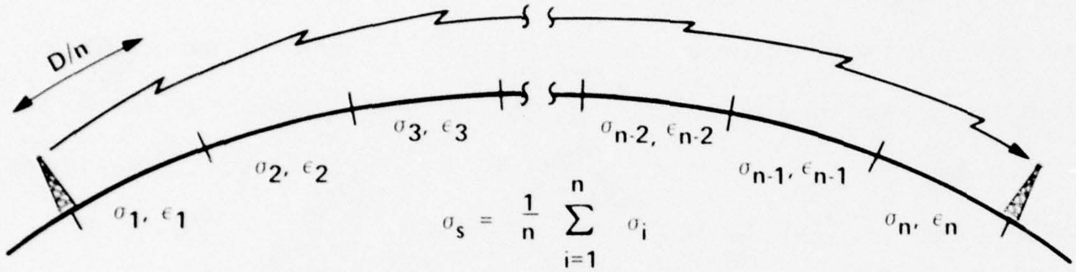


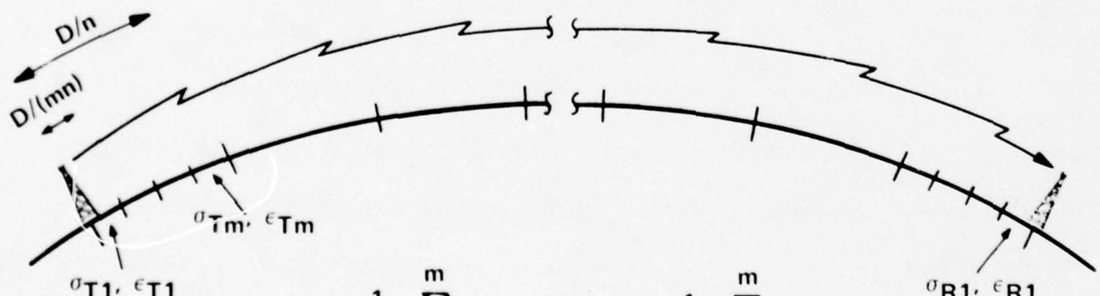
FIGURE 2-4(a). HOMOGENEOUS, USER SUPPLIED CONSTANTS



$$\sigma_s = \frac{1}{n} \sum_{i=1}^{n} \sigma_i$$

$$\epsilon_s = \frac{1}{n} \sum_{i=1}^{n} \epsilon_i$$

FIGURE 2-4(b). NONHOMOGENEOUS, SUDA METHOD



$$\sigma_{TS} = \frac{1}{m} \sum_{i=1}^{m} \sigma_{Ti} \qquad \sigma_{RS} = \frac{1}{m} \sum_{i=1}^{m} \sigma_{Ri}$$

$$\epsilon_{TS} = \frac{1}{m} \sum_{i=1}^{m} \epsilon_{Ti} \qquad \epsilon_{RS} = \frac{1}{m} \sum_{i=1}^{m} \epsilon_{Ri}$$

FIGURE 2-4(c). NONHOMOGENEOUS, MILLINGTON METHOD

constants are determined as the distance-weighted effective values as used by Suda in the special case of equal length path segments. Control then passes to begin evaluation of path characteristics using the effective ground parameters thus computed as shown in Figure 2-4(b).

In the event the user decides that a Millington approximate heterogeneous path calculation will be more appropriate (for example in the case of a mixed land-sea path) he must also input a quantity m which is the number of segments of length $d/(m \cdot n)$ into which the two path end segments are to be divided to calculate the required pair of effective ground constants for the Millington analysis as shown in Figure 2-4(c). The effective ground parameters at the receiver and transmitter path ends are thus calculated by the Suda method to provide the user an increased degree of spatial resolution control over the calculation.

The effects of wind on the apparent equivalent conductivity of the sea surface can substantially influence the coverage range of some HF signals. These effects are modelled using the Phillips isotropic ocean wave spectrum and the user may input an average wind velocity to compensate for known meterological conditions.

NUCOM/BREM provides the user with considerable flexibility in regard to the choice of ground parameters and inhomogeneous path analysis techniques. The parameter n controls the resolution of numerical map data employed by the Suda averaging technique and the parameter m is directly related to the effective ground parameter values in the region between the path ends and the boundaries of

the ground discontinuity in the Millington method. Thus the user has the option of either incorporating his own ground paramater data or relying on the ITS numerical map data with a selectable spatial smoothing function and the choice of Suda or Millington methods for inhomogeneous paths. This approach generalizes the conditions of applicability of the basic groundwave calculation techniques to include all reasonable situations with acceptable accuracy.

2.2.1 NWOMAP Data

NUCOM/BREM permits the user the option of either supplying his own effective ground parameters or permitting the data from the ITS Blue Binary data [11] to be automatically retrieved and used.

The ITS world conductivity numerical maps are held as spherical harmonic coefficients for a dimensionless variable WLD which is returned from the call to the subroutine NWOMAP.

The returned value of WLD is transformed by the subroutine GLOSS to an equivalent σ and ε value according to the algorithms given in Table 2-2. It should be noted that a linear relationship between σ and ε has been assumed a priori by ITS; this is consistent with a first order approximation to the empirical relationship between σ and ε of

$$\varepsilon \simeq 50\,(\sigma)^{1/5} \qquad (2\text{-}20)$$

as determined by Hanle, et al. [13]

It is left to the judgement of the user to decide whether the ground parameter data as returned from NWOMAP is adequate for his

TABLE 2-2

ALGORITHMS USED BY NUCOM II AND NUCOM/BREM TO DETERMINE σ AND ε FROM ITS WORLD NUMERICAL MAP COEFFICIENTS

VALUE OF WLD RETURNED FROM NWOMAP	-----TRANSFORMED GROUND PARAMETERS---- σ (MHO/m)	ε (NORMALIZED UNITS)
WLD $\geq$ 0.75	0.001	4.0
0.25 < WLD < 0.75 $\varepsilon = 3.985+15.203\sigma$	7.4995-9.998*WLD (0.001 $<\sigma<$ 5.0)	118-152*WLD (4 $<\varepsilon<$ 80)
0.25 $\leq$ WLD $\leq$ 0.25	σ = 4.0	80
-0.75 < WLD < -0.25 $\varepsilon = 3.998+15.200\sigma$	7.49995+9.9998*WLD (0.0001 $<\sigma<$ 5.0)	118+152*WLD (4 $<\varepsilon<$ 80)

particular application both in terms of data quality and spatial resolution. In order to provide guidance to the user NUCOM/BREM prints the values of σ and ε returned from NWOMAP for each point along the great circle path determined by the particular selection of n and m specified as input, as well as the Suda mean value when appropriate.

In order to help the user to visualize the ITS ground data we have performed the inverse mapping transformation on the world ground constant data in NUCOM II and NUCOM/BREM and present it as a geographical map in Appendix II of this report.

2.2.2 Inhomogeneous Path - Suda Method

The simplest commonly used technique to calculate the equivalent homogeneous ground parameters for an inhomogeneous path is the Suda method which provides essentially a distance weighted average value for ground constants along the path.

The user specified parameter n establishes the number of path segments of length (D/m) into which the path is to be segmented for Suda computation where D is the length of the path. The subroutines NWOMAP and GLOSS return the corresponding values of conductivity and dielectric constant for each segment of the path as described in Section 2.2.1. From these values are computed the homogeneous equivalent values defined as

$$\sigma_E = \frac{1}{n} \sum_{1}^{n} \sigma_i$$

and (2-21)

$$\varepsilon_E = \frac{1}{n} \sum_{1}^{n} \varepsilon_i .$$

According to Suda (op.cit.) this approach yields the best results when the values of ground parameters do not change rapidly along the path, for example on a transcontinental path which does not cross coastal boundaries or across the open sea.

In the case of groundwave signal paths which cross land-sea boundaries the Millington method is probably more appropriate.

2.2.3 Inhomogeneous Paths - Millington Method

Inhomogeneous groundwave paths which cross boundaries between regions with very different ground parameters such as paths across sea coasts are best handled with the semi-empirical Millington method [4].

Consider a nonhomogeneous path with ground parameters σ_T, ε_T at the transmitting end and σ_R, ε_R at the receiving end. Suppose the received signal field corresponding to a homogeneous path with parameters σ_R and ε_R is E_R, and the corresponding value for a uniform path with the parameters at the transmitter end of the path is E_T. Millington has shown that the field due to the two segment path is given by the geometrical mean of the received fields:

$$E = \sqrt{E_T E_R} \tag{2-22}$$

as long as the field is measured distant from the boundary interface location.

NUCOM/BREM permits a combination of Suda and Millington techniques. In the case where the user wishes a Millington analysis he specifies both a segmentation parameter n and an end parameter m.

The code will then perform a Suda average based on m steps of equal length for the segments of length (d/n) at each end of the path. The resulting two values, one for each end of the path, are used then for the Millington calculation. Two independent groundwave calculations are then performed using each end value in turn and the inhomogeneous path value is taken as the geometrical mean of the two resulting field strength values as described above.

2.2.4 Sea State Correction

The classical theory of groundwave propagation as treated by van der Pol and Bremmer (op. cit.) assumes a smooth and electrically homogeneous spherical surface. For a propagation path over such a surface it is necessary only to specify two ground constants, conductivity σ and the relative dielectric constant ε . These two constants characterize the electrical properties of the path and its loss (absorption) properties.

An alternative way to characterize the propagation path is through the definition of the ground surface impedance. It can be shown that for a plane wave incident upon a homogeneous ground at the angle τ_o, the impedance has to be of the following form:

$$Z = \frac{\eta_o}{\mu}\left[1 - \frac{\cos^2\tau_o}{\mu^2}\right]^{\frac{1}{2}}$$

where (2-23)

$$\mu = (\varepsilon - j\ 60\lambda\sigma)^{\frac{1}{2}}$$

$$\eta_o \cong 120\pi$$

and ε, σ, and λ are the relative dielectric constant, conductivity and the free space wavelength, respectively [14].

For grazing incidences ($\tau_o \simeq 0^o$) in a sea environment where the conductivity σ is very high and at frequencies below VHF the impedance expression takes an even simpler form [15]. Normalizing Z with respect to η_o, we can then write

$$Z/\eta_0 = \overline{\Delta} = R_\Delta - jX_\Delta$$

where (2-24)

$$R_\Delta = X_\Delta \simeq \frac{5.271*10^{-3}}{\sqrt{\sigma}}\sqrt{F_{MHz}} \quad .$$

In the above we have retained the conductivity explicitly instead of incorporating it into the constant. The reasons for this will become apparent shortly.

For homogeneous smooth surfaces the conductivity parameter σ accounts for the absorption due to ground losses. For rough surfaces such as the sea absorption is not the sole source of loss; scattering by the irregularities of the surface must also be accounted for. One approach to the problem of representing the losses over a rough finitely conducting surface is to postulate the existence of an apparent effective conductivity which represents all losses and is dependent on the surface roughness [15].

The criteria for surface roughness are usually expressed in terms of the mean height, the distribution of variation from the

mean, and the associated correlation function. For the sea surface formed only by surface winds a convenient and meaningful roughness criterion is that of the surface wind velocity. Assuming that the apparent conductivity is a function of the surface wind velocity, we may write

$$R_{\Delta}\ (\mathrm{ROUGH}) \simeq \frac{5.271*10^{-3}}{\sqrt{\sigma(\nu)}} \sqrt{f_{MHz}} \qquad (2\text{-}25)$$

where

$$\sigma\Big|_{\nu=o} = 4 \text{ mho/m} ,$$

or, written differently,

$$R_{\Delta}\ (\mathrm{ROUGH}) \simeq \beta(\nu) * \sqrt{F_{MHz}} \qquad (2\text{-}26)$$

and therefore

$$\sigma(\nu) = 2.778 * 10^{-5}\ (1/\beta(\nu))^2 \ . \qquad (2\text{-}27)$$

To determine the precise form of the apparent conductivity the above functions must be derived from suitable models of the surface structure and impedances.

For the so-called Phillips (isotropic) ocean wave height spectrum and the model of the surface impedance as given by Barrick (op.cit), the following relation has been derived by Kaliszewski [15]:

$$\beta(\nu) = 2.635*10^{-3} + 8.784*10^{-5} \qquad (2\text{-}28)$$

where ν is the surface wind velocity in meters/second.

Expressions similar but not linear in ν can be obtained for the Neuman-Pierson ocean wave height spectrum [17].

Substitution of Eq. (2-28) into Eq. (2-27) then gives $\sigma(\nu)$. A plot of $\sigma(\nu)$ for the Phillips and Neuman-Pierson ocean wave height spectra is shown in Figure 2-5. The abscissa in that figure is labeled in both meters/second and sea state parameters.

We thus construct an equivalent smooth sea surface in place of a rough one and assigned to it the property of an apparent equivalent conductivity. As is evident from Figure 2-5, the value of the apparent conductivity is affected by the surface roughness and is smaller than the rougher (or more disturbed) sea surface. The difference in values of the conductivity for smooth and rough surface represents the contribution to the propagation losses of the surface scatter.

That such a difference can be significant can be seen from Figure 2-6 where we have plotted the difference in the propagation losses obtained via the NUCOM/BREM groundwave prediction program for the indicated parameters. The difference is termed the excess loss (i.e., relative to a smooth surface) and is shown as a function of frequency. Note the resonant nature of the curve with the peak at about 14 MHz. Also plotted are values obtained by Berrick (op. cit.) from a considerably more extensive computation involving the full complex surface impedance of the surface.

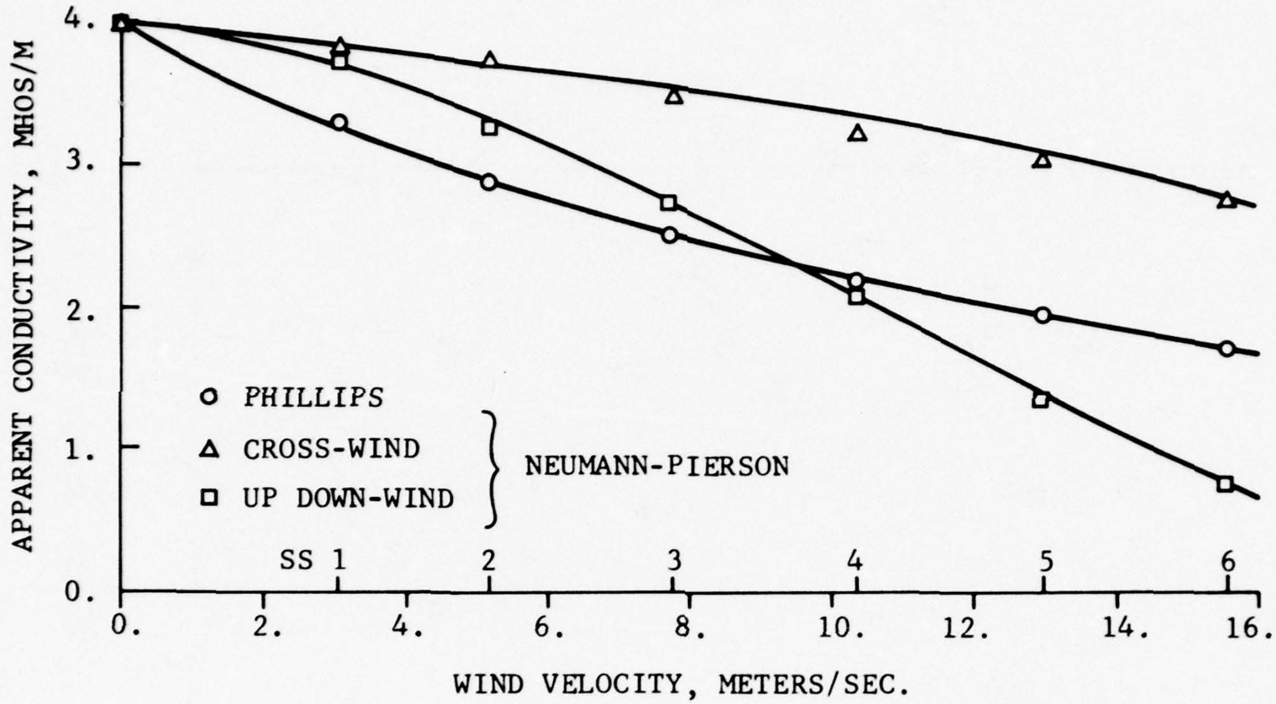


FIGURE 2-5. APPARENT CONDUCTIVITY OF A ROUGH SEA

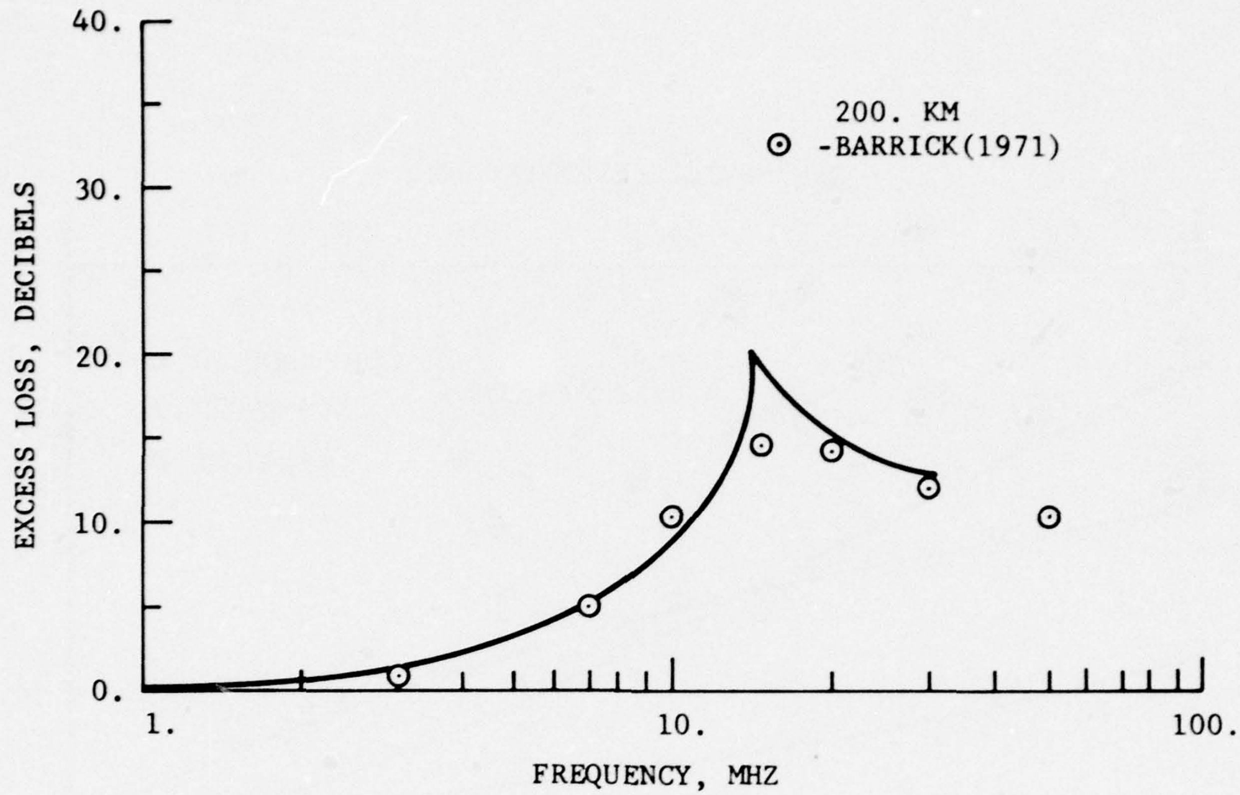


FIGURE 2-6. FREQUENCY DEPENDENCE OF EXCESS LOSS DUE TO ROUGH SEA. (GROUND-BASED, VERTICAL ANTENNAS)

In summary, NUCOM/BREM employs a computationally efficient groundwave prediction subroutine based on the analysis for a smooth, homogeneous earth and modifies it for use in rough sea environments. The modification takes the form of an algorithm for the apparent sea conductivity by which, in turn, is a function of the surface wind velocity (i.e., sea state). The input to NUCOM/ BREM can take the form of a wind velocity, in meters/second, or a precalculated value of the apparent conductivity (say, from Figure 2-5).

It has been suggested by Wait [18] that the equivalent surface impedance approach to the disturbed sea surface may be unsuitable at the exact resonance frequency and the user should exercise caution in this special case.

2.3 Antenna Pattern Considerations

NUCOM II permits the user to specify two methods for treating antenna gains. Either he may specify that both transmitter and receiver are using isotropic antennas or alternatively he may supply his own antenna patterns. NUCOM II has a limited antenna pattern facility as shown in Figure 2-7(a). User supplied antenna pattern tables expressed in dB above isotropic are input for each one-degree of elevation angle (relative to the horizon) from 1° to 40°. For angles in the range $0^{\circ} \geq 1^{\circ}$ the value at 1° is used; for angles > 40° the value at 40° is used. The input antenna gain patterns supplied by the user are applied to the incoming ionospheric signal rays in NUCOM II by the power flux equation (Eq. 1-2) in subprogram COMEFF independent of signal polarization (which is assumed to be random).

Table 2-3 summarizes the additional antenna input features available in NUCOM/BREM. As shown in Figure 2-7(b), the range of input antenna gain elevations has been extended to $\pm 90^{\circ}$ and both vertical and horizontal polarization patterns may be input independently. Furthermore the previous restrictions on the amount of antenna pattern data input have been relaxed for NUCOM/BREM by allowing a user specified minimum and maximum angle separately for transmitter and receiver patterns.

We have chosen to maintain the antenna pattern card input formats and angular conventions from NUCOM II to eliminate conversion problems for pattern decks punched for NUCOM II. In particular we have retained the reference angle convention of 0° corresponding to the local horizon.

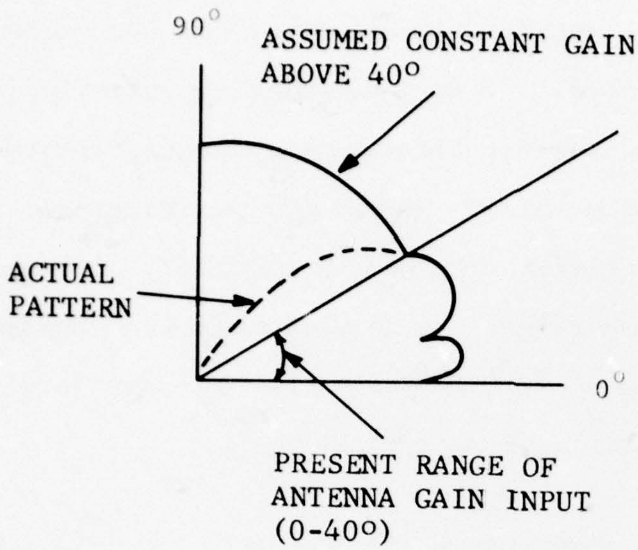


Figure 2-7(a). Original Antenna Pattern Limitations in NUCOM II

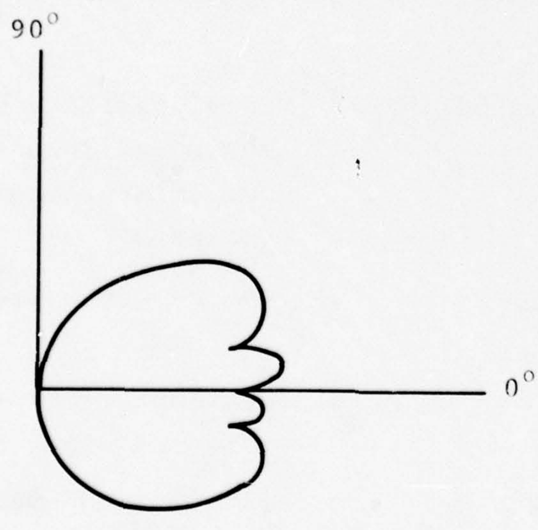


Figure 2-7(b). Extended Antenna Input Form Includes Data for Evaluations in the Range $-90^\circ \leq \theta \leq +90^\circ$

The official MIL coordinate system for airborne antenna patterns[21] is based upon the standard spherical (θ,ϕ) coordinate system and is shown in Figure 2-8. It is customary to describe θ measured from the local zenith and ϕ measured in a counterclockwise direction from the nose of the aircraft. Refining polarization components in this coordinate system avoids the ambiguity associated with the terms horizontal and vertical for angles near the zenith. Throughout the present work we shall use the terms "E_ϕ" and "horizontally polarized field" interchangeably.

Table 2-3

Comparison of input antenna features between NUCOM II and NUCOM/BREM

NUCOM II	NUCOM/BREM
a) Range limited to 1°-40° in 1° steps	a) Range $\pm$ 90° in 1° steps
b) All 40 values must be supplied by user	b) User specifies minimum and maximum values separately for transmitter and receiver patterns
c) Full eight frequencies must be input	c) One to eight frequencies may be input
d) No polarization	d) Horizontal and vertical gain patterns input independently
e) Out of range values fixed by last value	e) Out of range values assumed isotropic

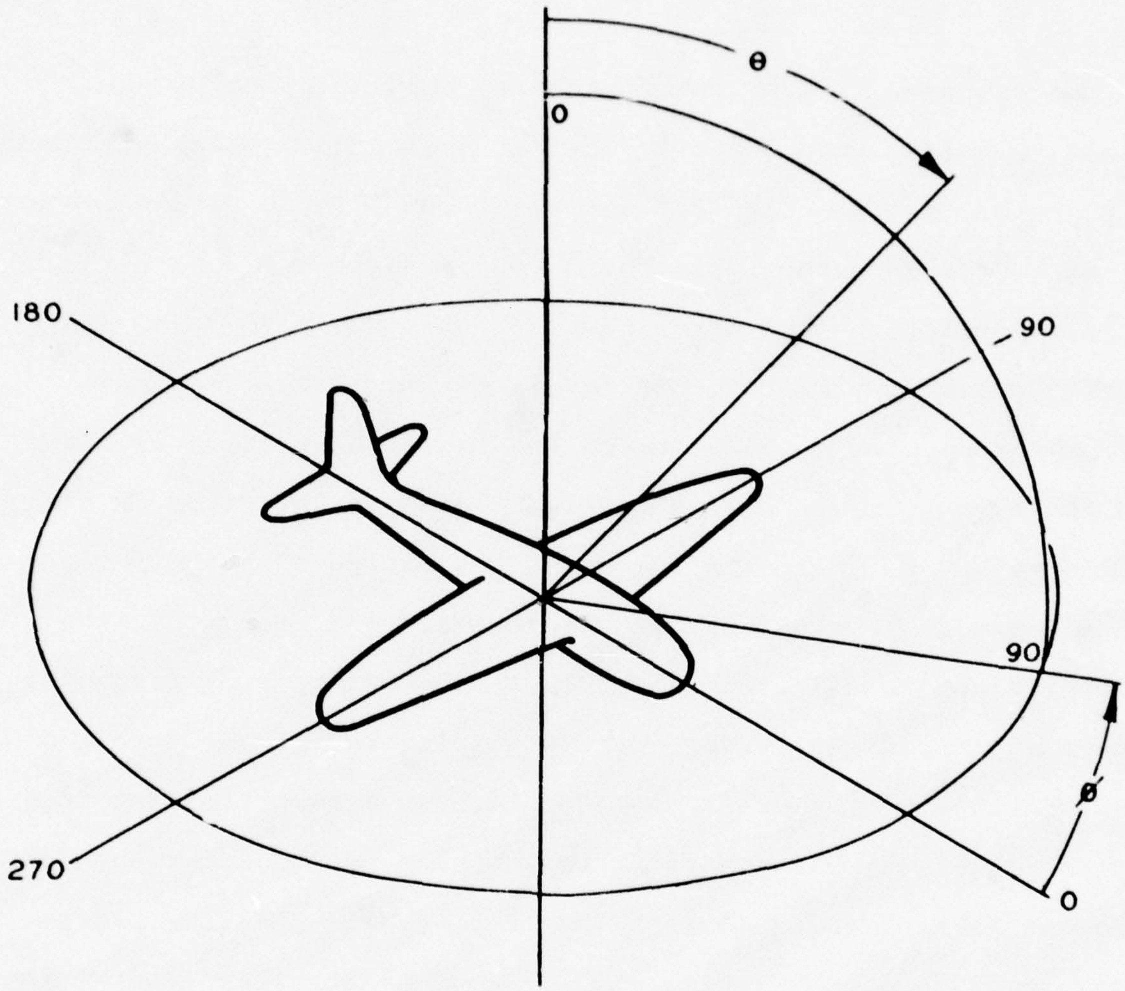


Figure 2-8. MIL coordinate system for airborne antennas.

The term "vertical polarization component" is generally used interchangeably with "E_θ" except in the context of ambiguous geometries where E_θ as defined as in Figure 2-8 will be used explicitly.

The airborne HF liaison antennas in popular usage at the present time fall into several distinct design categories although their performances tend to be rather similar. These categories are:

i) Notch antennas, e.g., wing or tail notch

ii) Cap antennas, e.g., wing tip, tail, and nose-caps, and

iii) Extended wire antennas, e.g., tail-to-fuselage wires.

The problem of calculation of the radiation pattern of a real airborne HF antenna is almost hopelessly intractable from an analytic point of view due to the influence of the airframe on the pattern. Figure 2-9 illustrates the charge separation and field fringing effects which are of particular concern in the lower HF frequency range where the signal wavelength is still fairly large compared with the dimensions of the airframe. Consider an aircraft flying through a uniform vertical electrostatic field. The field will result in a charge separation as shown in Figure 2-9(a) with positive charge on the lower portion of the body. Because of the field line fringing of the field about the airframe, the local field strength along the upper and lower centerlines will exceed the imposed field while the strength along the sides at the boundary of the charge separation region will approach zero.

The same pattern of charge distribution will result from the imposition of a relatively low HF frequency signal field except that the polarization will vary with $\cos(\omega t)$. If the impressed field were

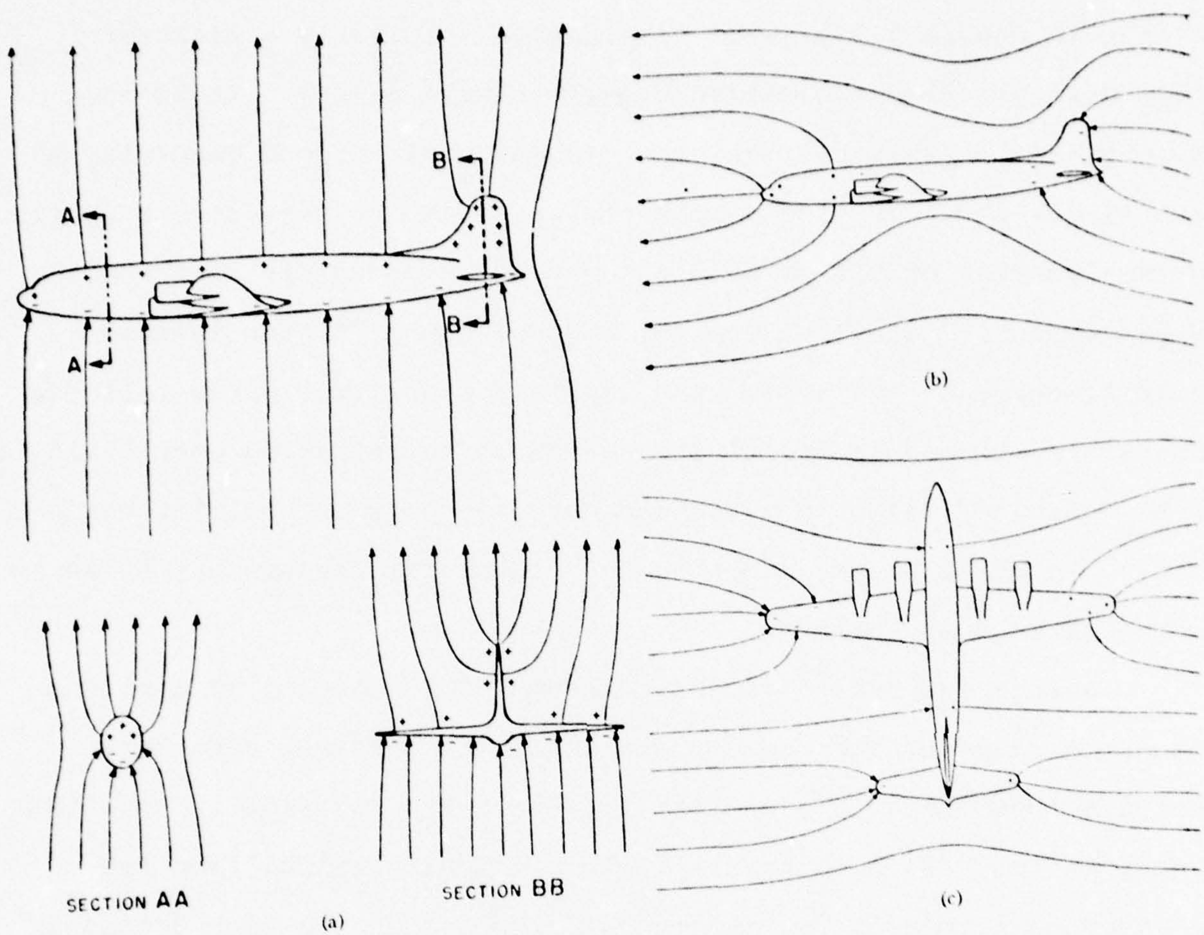
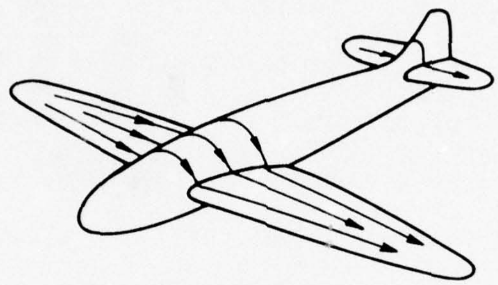


Figure 2-9. Charge separation and E-field fringing on airframe at HF.

polarized in the direction of flight, a charge distribution similar to that in Figure 2-9(b) will be produced; similarly a transverse field will polarize the airframe as in Figure 2-9(c). It is then obvious that a particular antenna element will respond generally to each of the three imposed components in a fashion dependent strongly on the location of the antenna element relative to the airframe. As discussed in detail by Granger and Bolljahn[22], the intense field fringing at the top of the vertical stabilizer makes tail cap antennas particularly useful when vertical polarization sensitivity is to be optimized; likewise wing-cap antennas perform well for horizontal fields although in both cases structural factors may outweigh communications advantages.

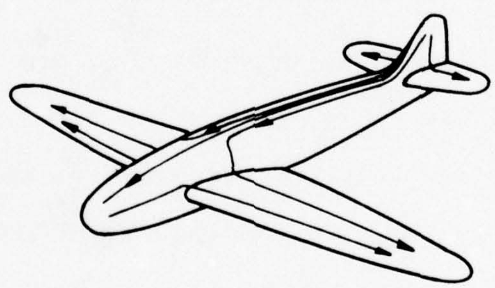
Numerous authors[23,24] have attempted to compute HF airborne antenna performances by decomposition of the airframe structural elements into elementary current filaments but the results have been disappointing. Much of the analytic difficulty arises from the near-resonant behavior of structural elements in the high frequency range. Figure 2-10 shows the two dominant types of resonance modes excited by HF fields which are conveniently classified as symmetric and antisymmetric[25]. Generally, both modes are excited by actual coupling elements and consequently the pattern symmetries to be expected from simple current decompositions are rarely observed in practice[26].

The outstanding failure of attempts to predict airborne antenna patterns has led to a variety of empirical methods for pattern determination and evaluation including electrostatic[27] and scale model RF[28] measurement procedures, and semi-empirical and statistical techniques[29-32].



(a)

SYMMETRIC MODES



(b)

ANTISYMMETRIC MODES

Figure 2-10. Dominant airframe resonance modes for HF range.

Wong[33] and Granger[25] have presented data showing the relative performances of various types of airborne antennas as expressed in terms of the "radiation pattern efficiency" which is defined as the ratio of power radiated in the elevation angle range of $\theta = 90^\circ \pm 30^\circ$ to the total radiated power. Figure 2-11(a) shows Wong's results for a CL-28 and Figure 2-11(b) presents Granger's data for a C-54. The marked resonant effect around 8 MHz of the phased wing caps on the C-54 is interpreted as a structural resonance.

Wong[33] has also evaluated the relative polarization efficiencies of a variety of antenna types on the CL-28. Figure 2-12 shows the ratio of vertically polarized power to total radiated power as a function of frequency. The complexity of structural resonance phenomena is quite evident.

As an aid to users of NUCOM/BREM we here provide some typical measured patterns for several classes of HF airborne liaison antennas to provide guidance in the modeling of airborne communications links. Tabulated patterns in the format required by NUCOM/BREM are listed in Appendix B.

Figures 2-13(a) through 2-13(c) present measured model patterns for a wing notch antenna on the Vulcan bomber. Figures 2-13(a) and (b) show the azimuthal ($\emptyset$) pattern at 2.02 and 21.5 MHz respectively[34]. Note the essentially omnidirectional behavior at low frequencies and the conspicuous lobe-splitting at higher frequencies. Figure 2-13(c) shows the corresponding vertical plane pitch pattern for both polarization components at 2.02 MHz. The pattern nulls at $\theta = 0^\circ$ and 180° for the horizontal component are typical of wing notch pattern behavior[35].

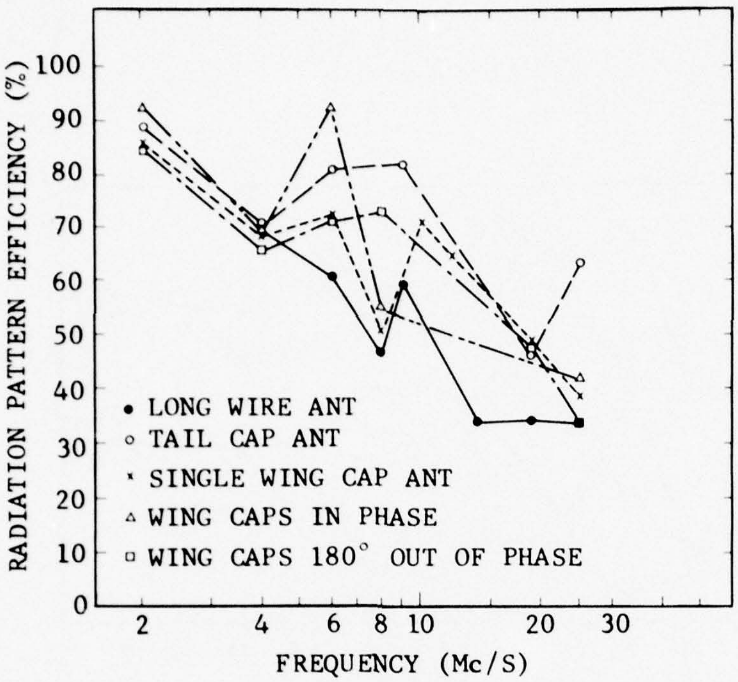


Figure 2-11(a). Relative pattern efficiencies for various types of airborne HF antennas on C-54 after Granger.

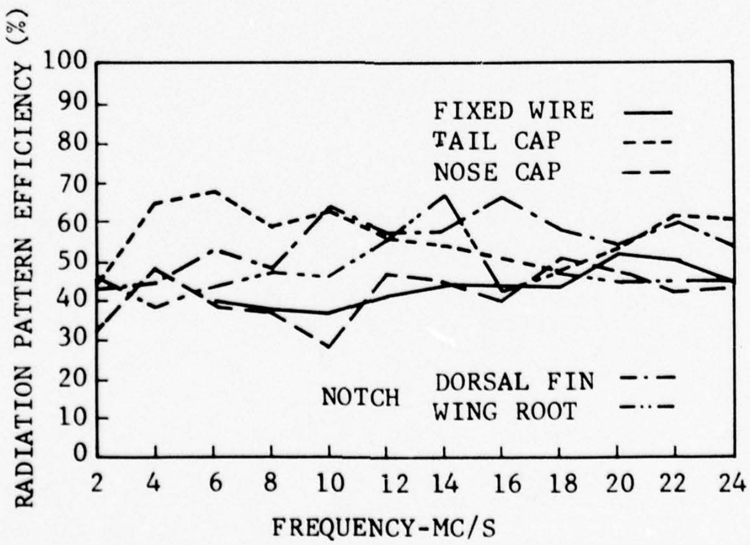


Figure 2-11(b). Relative pattern efficiencies for various types of airborne HF antennas on CL-28 after Wong.

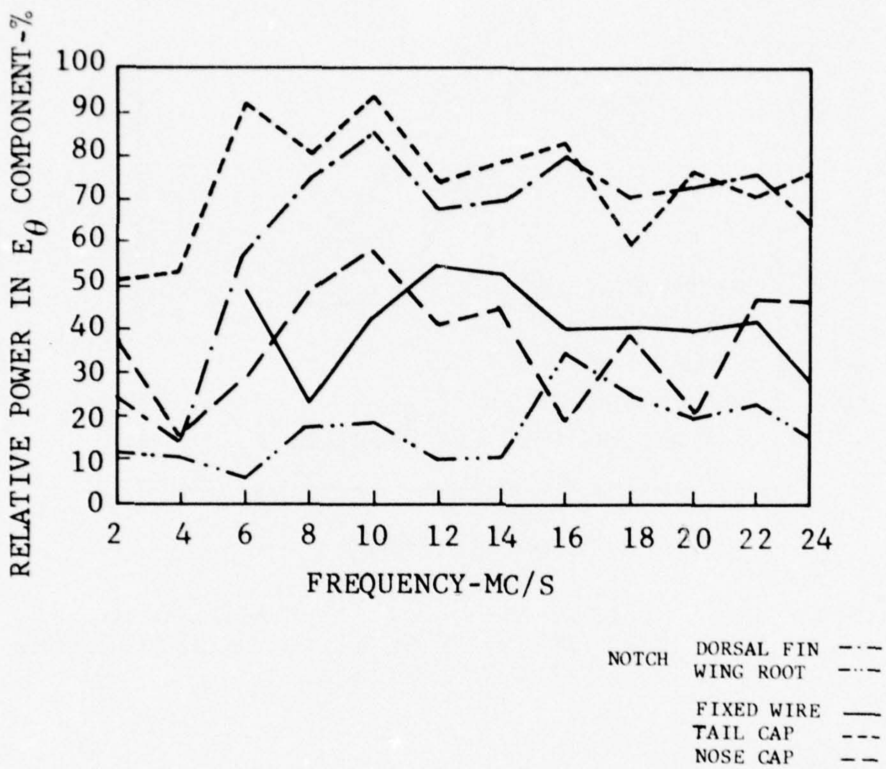


Figure 2-12. Relative power in vertical polarization component for various HF airborne antenna types after Wong.

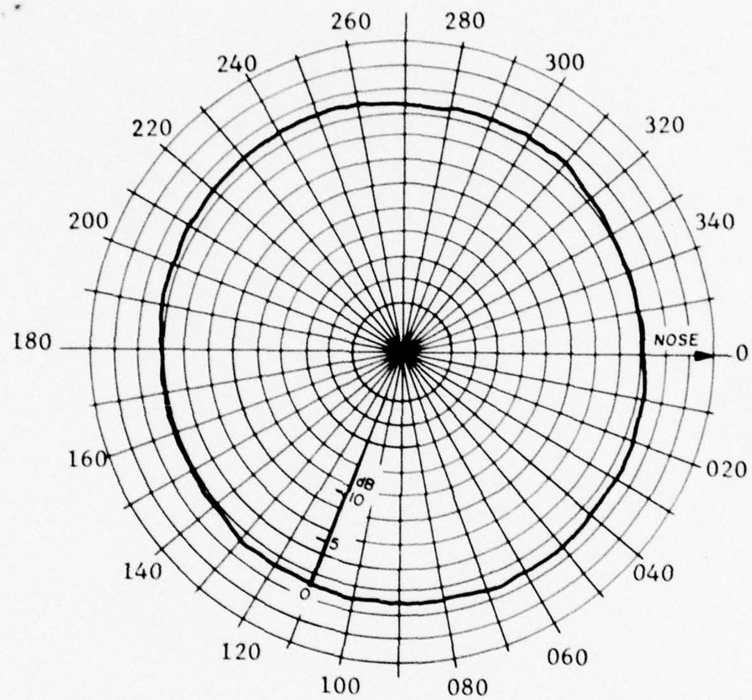


Figure 2-13(a). Azimuthal power pattern for using notch antenna; vertical component in dBi at 2.02 MHz.

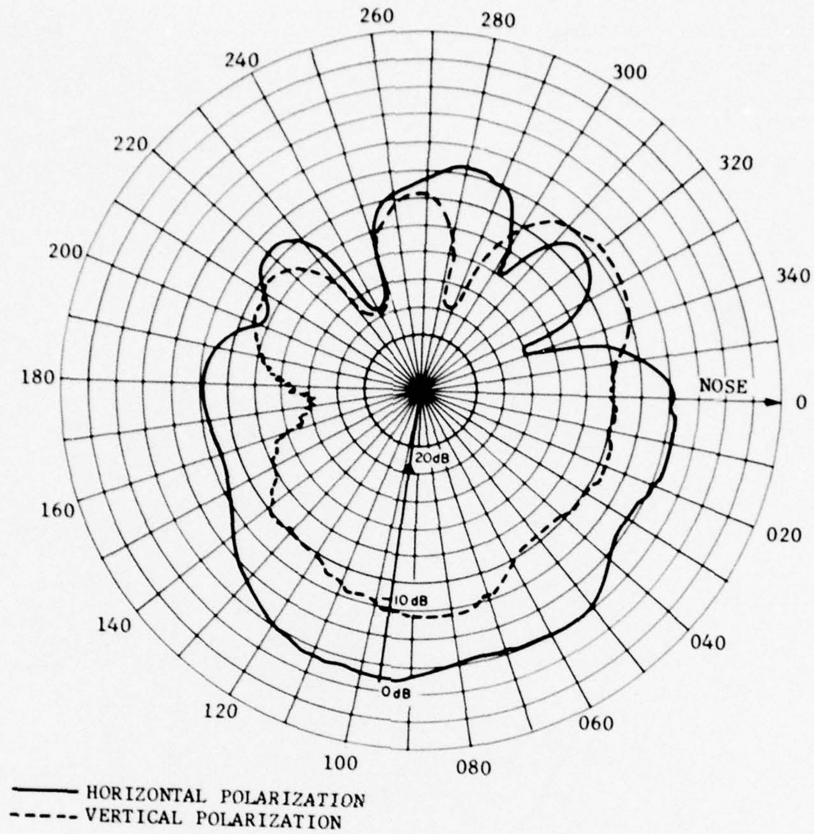


Figure 2-13(b) Azimuthal power pattern of wing notch antenna of 2-13(a) except at 21.5 MHz.

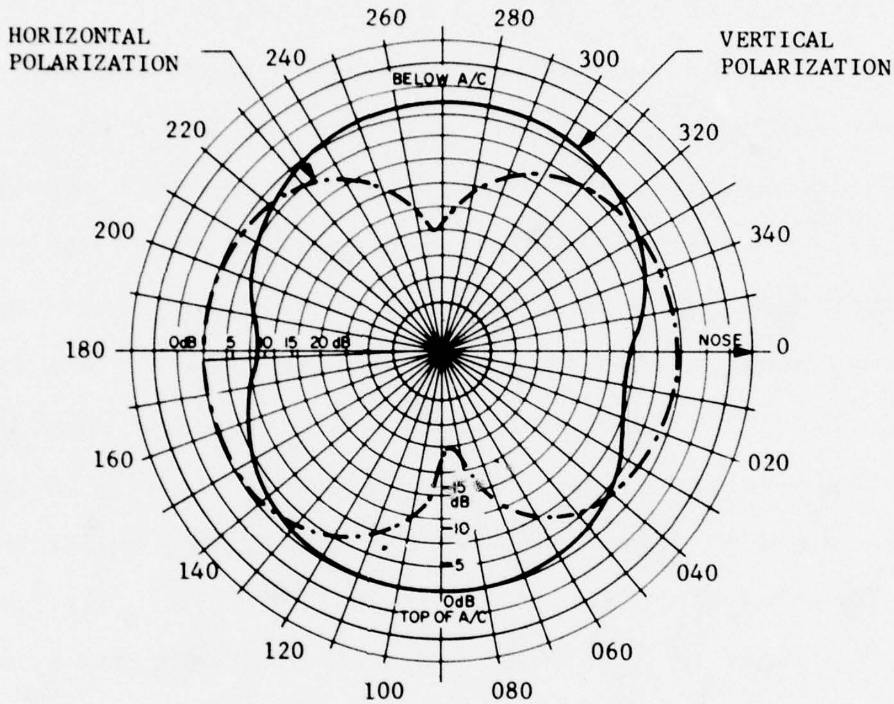


Figure 2-13(c) Vertical (E_θ) pattern for using notch antenna at 2.02 MHz.

Notch antennas are employed on the fuselage less commonly than on leading wing surfaces. Figures 2-14(a) and (b) show measured model azimuthal (Ø) patterns for a dorsal notch on the Vulcan airframe at 6.6 and 23.3 MHz respectively.

Whereas notch antennas consisting of short segments insulated from wing surfaces essentially act as shunt feeds to the structural elements of the airframe[36-38], the wing and tail cap antennas are usually actively driven against the airframe. The radiation efficiency of a cap antenna appears to depend strongly upon area of the cap segment insulated from the airframe[39] but the form of the pattern (i.e., shape) is supposedly rather invarient to the physical dimensions of the cap. Figures 2-15 and 2-16 show the model measured patterns for wing and tail cap antennas respectively for the Douglas DC series of airframes[28]. For this frequency (2 MHz) at least the patterns are seen to vary smoothly with cap area.

Extended wire antennas operating at frequencies near those of structural element resonances are probably the most difficult to generalize. Figures 2-17(a) through 2-17(b) show measured vertical polarization model gains on a 1/25 scale EC-135 for a single tail-fuselage wire[41]. These patterns extrapolated to $\theta = 0^{\circ}$ have been digitized and are presented in Appendix B in a format suitable for inclusion into NUCOM/BREM. The horizontal polarization component has been derived from the vertical component gain by applying the corrections due to Wong[33].

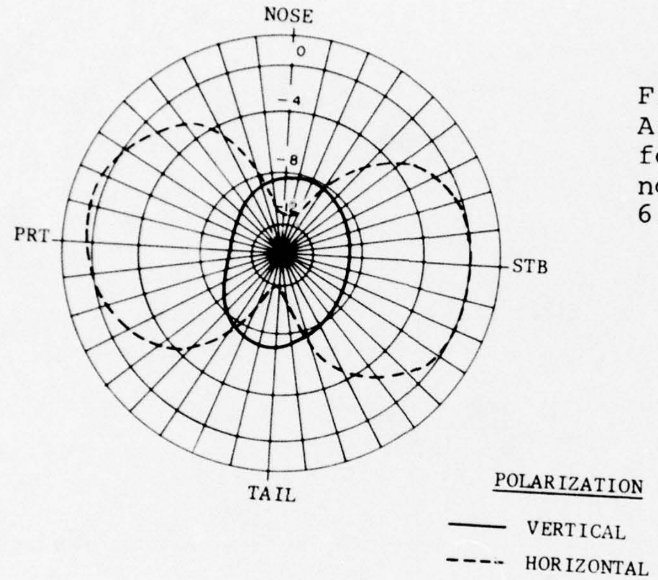


Figure 2-14(a). Azimuthal pattern for dorsal fuselage notch antenna at 6.6 MHz.

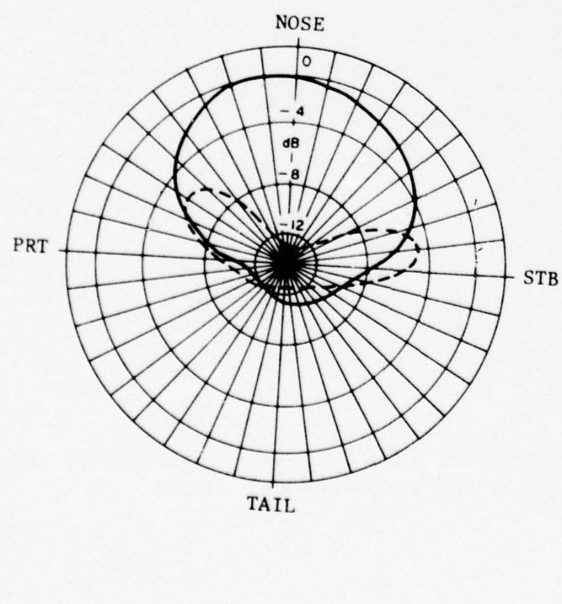


Figure 2-14(b). Azimuthal pattern for dorsal fuselage notch at 23.3 MHz.

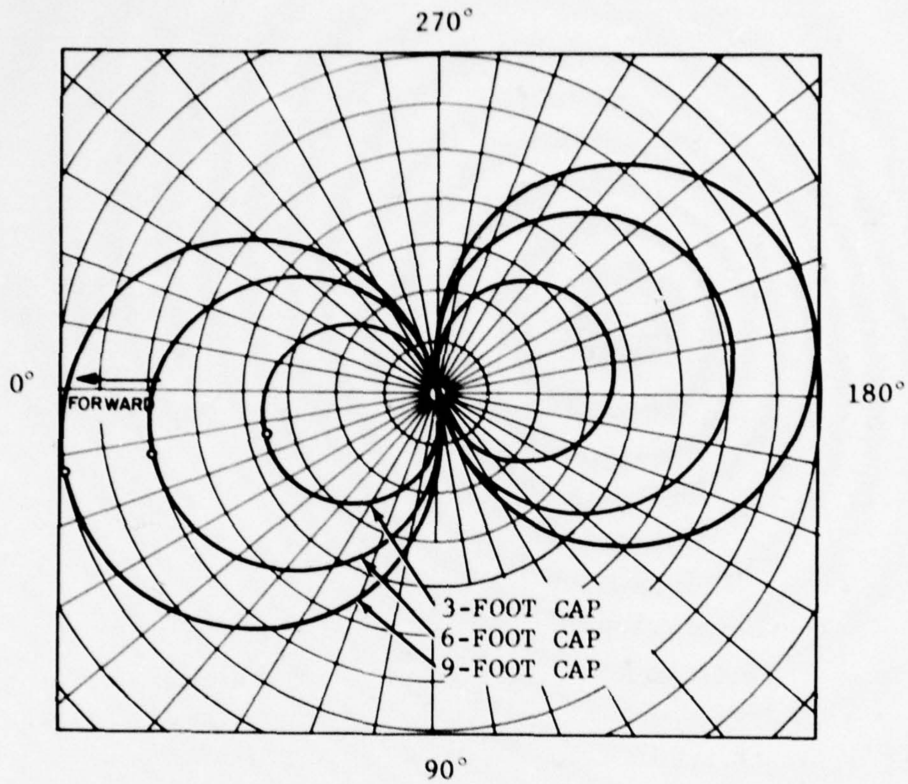


Figure 2-15. Measured pattern of using cap antenna on DC airframe as a function of cap area.

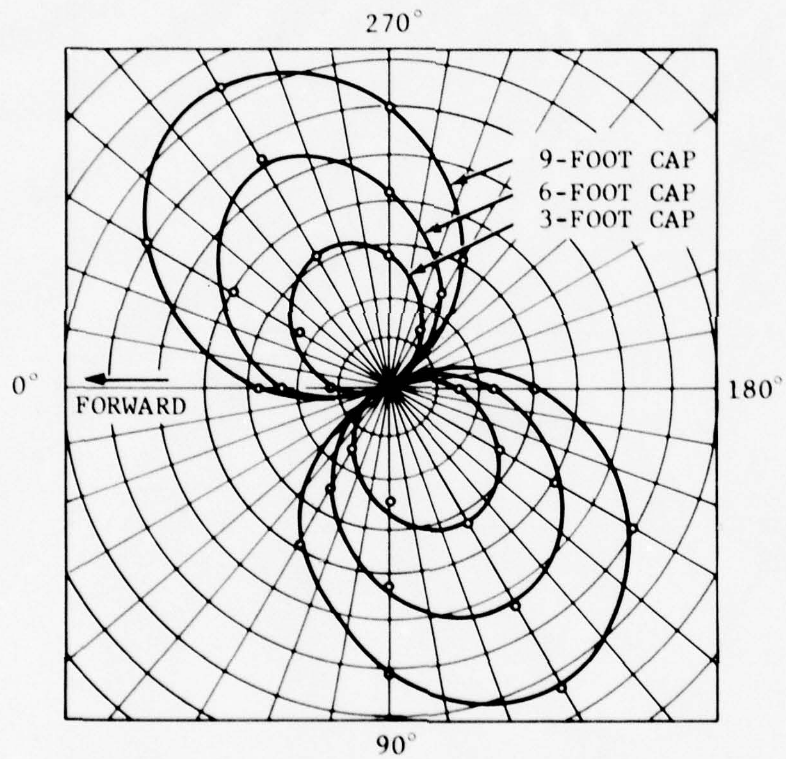


Figure 2-16. Measured pattern of tail cap antenna on DC airframe as a function of cap area.

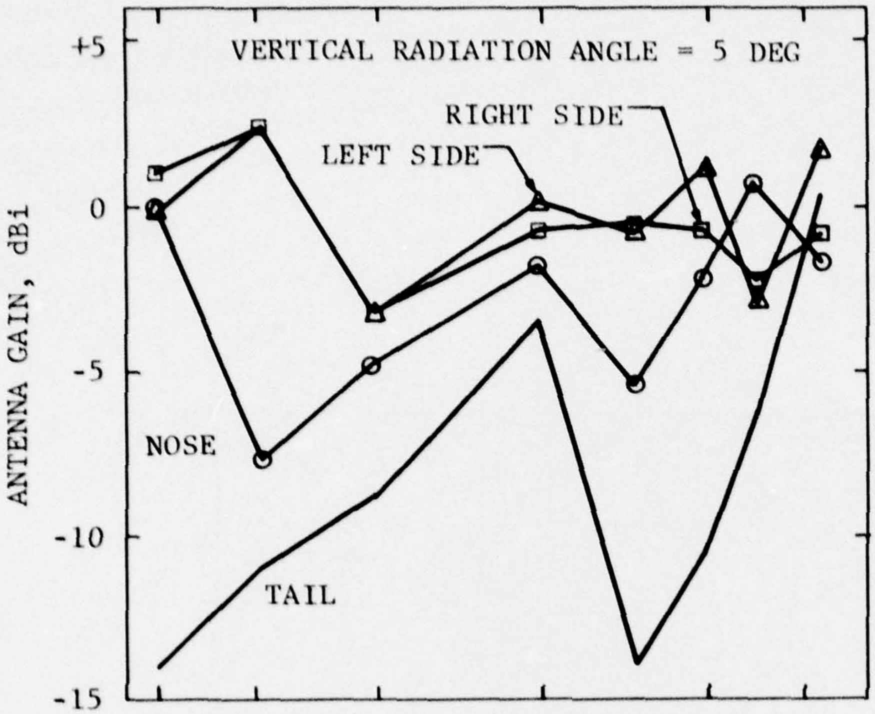


Fig. 2-17(a).

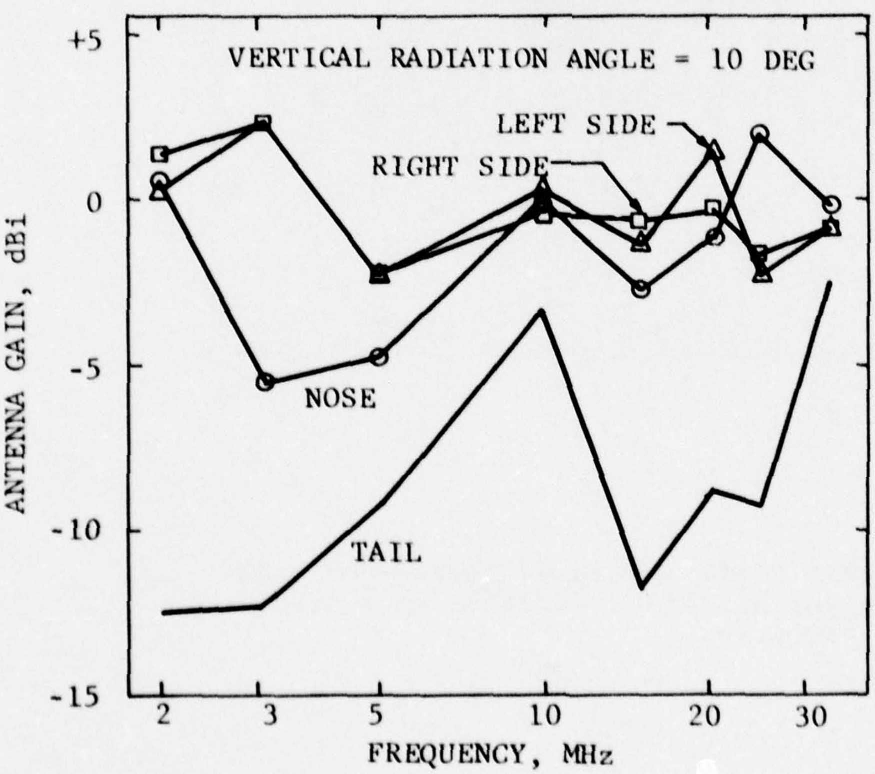


Fig. 2-17(b).

Figures 2-17(a)&(b) Measured model patterns for EC-135 tail-to-fuselage wire antenna.

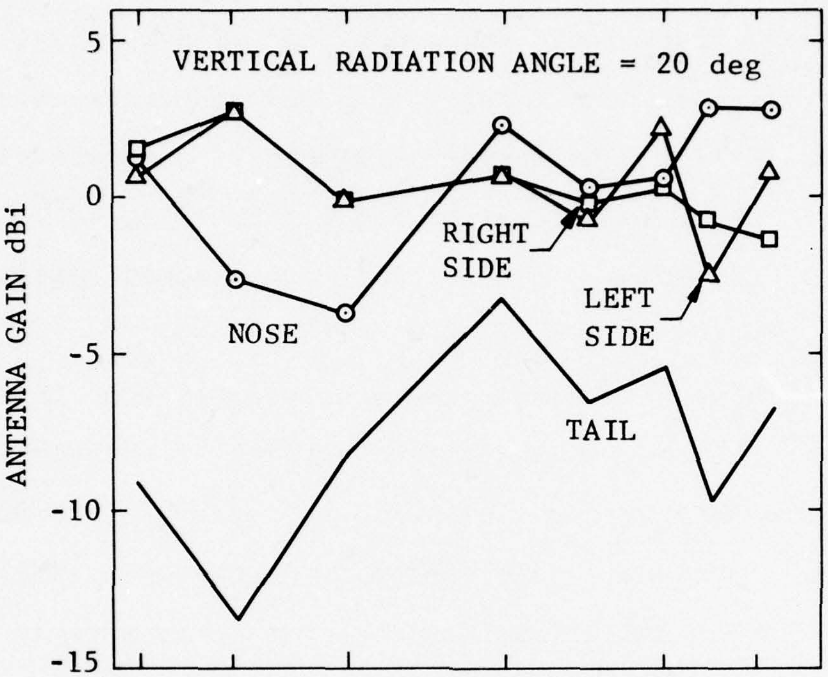


Fig. 2-17(c).

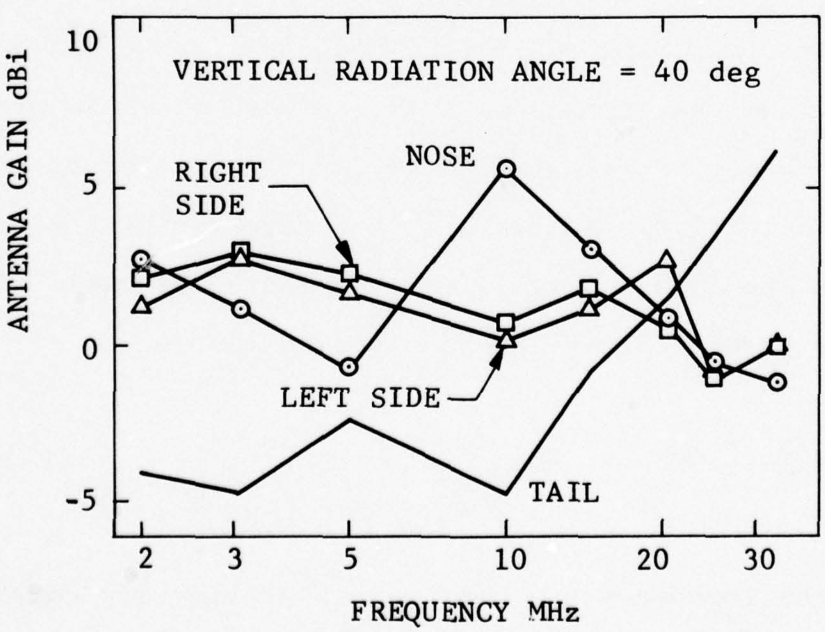


Fig. 2-17(d).

Figures 2-17(c)&(d). Measured model patterns for EC-135 tail-to-fuselage wire antenna.

2.4 Antenna and Power Compensations

NUCOM II and NUCOM/BREM calculate the total path loss for each ionospheric ray path assuming isotropic radiators at each terminal and unity transmitted power density. The vertical plane power patterns for both transmitting and receiving antennas are input to NUCOM II in the form of tables giving power gain in dBi for each one degree of elevation angle from 1^{o} to 40^{o}. Above 40^{o} and below 1^{o} the values at 40^{o} and 1^{o} are assumed respectively.

In NUCOM/BREM we have elaborated considerably upon this approach to permit the user to input both horizontal and vertical polarization component vertical plane power patterns independently. Furthermore the input angle calculation range has been extended to a full $\pm 90^{o}$ to permit inclusion of airborne antenna pattern effects for terminals located at elevation angles as high as the zenith.

Adjustment of uncompensated received signal power levels for user input antenna patterns and actual radiated power is performed as follows. Suppose the standard 1 kW ERP transmitter of Bremmer produces a calculated r.m.s. field at the receiver of E microvolts/meter from the standard short optimally oriented electric dipole radiator. The power flux at the receiver is then given by

$$P_F = \frac{E^2 * 10^{-12}}{\eta_o} \quad \text{Watts/m}^2 \tag{2-28}$$

where η_o is the impedance of free space approximately equal to approximately 120Π or 377.0Ω. The power then received by an

isotropic radiator located at the receiver is then equal to the product of the power flux and the effective capture area of the isotropic antenna or,

$$P = \frac{2 * 10^{-12}}{\eta_o} * \frac{\lambda^2}{4\pi} \qquad (2\text{-}29)$$

where λ is the wavelength.

Expressed in dBW this becomes

$$P = 20 \text{ Log}_{10} \lambda + 20 \text{ Log}_{10} E - 156.755 \text{ dBW} \qquad (2\text{-}30)$$

Since the gain of a short optimally oriented dipole is 1.761 dB relative to an isotropic radiator, the received compensated power may be expressed as

$$P_C = 20 \text{ Log}_{10} E + 20 \text{ Log}_{10} \lambda - 188.516 + G_R + G_T + P_T \text{ dBW} \qquad (2\text{-}31)$$

where G_R and G_T are the power gains in dB of the receiving and transmitting antennas relative to isotropic for the polarization component of interest and P_T is the actual radiated power density in dB relative to one Watt/Hz. This quantity P_C is then incorporated into the ionospheric ray received power sum to yield the total power for all received signal modes. Up to four nonionospheric power components may be involved: the horizontal and vertical components of the direct ray between elevated line-of-sight terminals and the corresponding components of the reflected ray.

In the most general case of two line-of-sight aircraft with ionospheric paths the all mode power sum becomes that of Equation 1-2,

$$P_{TA} = 10 \operatorname{Log}_{10} \left(\frac{P_{TI} + P_{TV} + P_{TH}}{P_{NV} + P_{NH}} \right) \text{ dBW} \qquad (2\text{-}32)$$

where

P_{TI} is the total received ionospheric power density,

P_{TV} is the total received non-ionospheric vertically polarized signal power density,

P_{TH} is the total received non-ionospheric horizontally polarized signal power density,

P_{NV} is the received atmospheric vertically polarized noise density, and

P_{NH} is the received atmospheric horizontally polarized noise density.

Each of the two non-ionospheric power components, P_{TV} and P_{TH}, will consist of both direct and reflected components,

$$P_{TV} = P_{DV} + P_{RV}, \text{ and}$$

$$P_{TH} = P_{DH} + P_{RH} \qquad (2\text{-}33)$$

where

P_{DV} is the compensated vertically polarized power density from the direct ray,

P_{DH} is the compensated horizontally polarized power density from the direct ray,

P_{RV} is the compensated vertically polarized power density from the reflected ray, and

P_{RH} is the compensated horizontally polarized power density from the reflected ray.

2.5 Horizontal Noise Corrections

Since the performance of HF links using both ionospheric and nonionospheric modes of propagation is usually limited by the received noise level, in the end the goodness of a propagation prediction made from a code such as NUCOM will depend as much upon the accuracy of the atmospheric or man-made noise level figures as it will upon the propagation analysis.

The noise figure values used in NUCOM II (and in all ionospheric propagation codes for that matter) are directly adapted from the data presented in CCIR Report 322 [42]. This data was taken by the worldwide ARN-2 instrumentation network and provides noise parameters assuming "a short vertical antenna over a perfectly conducting ground plane". As CCIR 322 is the international standard it is appropriate to quote their findings regarding noise polarization and directional effects,

> 8. The influence of the directivity and polarization of antennae
>
> All the noise information presented in this Report, including the examples given in the last section, relates to a short vertical receiving antenna. Although such an antenna may be used in practice at low frequencies, long-distance communication at high frequencies is normally achieved by the use of a highly-directional antenna. Some allowance must therefore be made for the effects of directivity and polarization on the signal-to-signal noise ratio.
>
> It is assumed that the signal gain is reasonably well-known, although it is dependent on the relative importance of the various propagation modes, which varies with time. The effective noise factor of the antenna, insofar as it is determined by atmospheric noise, may be influenced in several ways. If the noise sources were distributed isotropically, the noise factor would be independent of the directional properties. In practice, however, the azimuthal direction of the beam may coincide with the direction of an area where thunderstorms are prevalent, and

the noise factor will be increased correspondingly, compared with the omnidirectional antenna. On the other hand, the converse may be true. The directivity in the vertical plane may be such as to differentiate in favour of, or against, the reception of noise from a strong source. The movement of storms in and out of the antenna beam may be expected to increase the variability of the noise, even if the average intensity is unchanged.

Experimental information on the effects of directivity is scarce, and in some respects conflicting. In an equatorial region (Singapore), the median value of F_a for certain directional antennae was found to be somewhat higher (about 4 db on the average), than that for a vertical rod antenna over the same period. This figure is considerably lower than the maximum possible antenna over the same period. This figure is considerably lower than the maximum possible antenna gain, as would be expected from the widespread nature of the storms, but the fact that there was, on the average, some gain in noise in a wide range of storm conditions suggests that there was, on the average, some gain in noise in a wide range of storm conditions suggests that there was a tendency for the noise to be received more from the lower angles of elevation. In the F.R. of Germany also, directional antenna had, on the average, higher noise factors[43,44]. On the other hand, in experiments in Australia, the average noise factors of several antennae, beamed in different directions, were a few decibels lower than that of a vertical rod antenna, the interpretation being that there was significant noise incident at high angles[4 5]. It appears therefore that, in general terms, the gain in signal-to-noise ratio is likely to be approximately that in the signal alone (which may, however, be less than the optimum gain), and that if more precise figures are needed, it is necessary to take into account the storm locations and the critical frequencies of the ionosphere in addition to the antenna polar diagram. More investigations are required before the allowances can be made reasonably precise, but it appears that the differences will usually be less than 6 db.

Even less information is available on the effects of antenna polarization, but for a first approximation, it may be assumed that the received noise would be comparable with either polarization, provided the antenna height is large compared with the wavelength.

Gallenberger and Bickel [46] report that measurements of the vertical and horizontal components of noise at VLF to elevations of 20,000 feet indicate that that the horizontal component is down as much as 30 dB. It however must be pointed out that 20,000 feet is still less than $\lambda/2$ at VLF and that such behavior is not to be expected at HF, above a few wavelengths. It is therefore not unreasonable to assume that the noise power for horizontal polarization will be the same as that for vertical polarization above, say, 10λ or about 1 km. Below that height the amplitude of horizontally polarized noise will drop in amplitude to a low value near the surface of the earth, due to the behavior of the Fresnel reflection coefficient for horizontally polarized fields near the surface. The precise behavior of the horizontal noise value with height has not been experimentally investigated and will depend on some complex function of the precise reflective properties of the ground and the vertical and azimuthal disturbances of incoming ionospherically propagated HF noise.

It has been suggested by Bickel [47] that an exponential height model should be an acceptable first approximation for the behavior of horizontally polarized noise power at HF. We have therefore used an exponential function with a user specified height constant to allow fitting of empirical data should the user so desire. It should be pointed out however that the height regime where attenuation of the horizontal noise power due to ground effects is important at HF is below

the heights used for most C^3 airborne assets.

An even more uncertain question is that of the relationship between receiver antenna polarization and pattern characteristics and the received noise power P_N. Without a detailed description of the distribution of each polarization component of noise with both θ and ϕ no meaningful antenna correction can be accomplished. This no doubt explains why the CCIR figure RNOYS is employed in NUCOM II without further antenna pattern compensation.

Since airborne antennas may feature predominantly horizontal polarization characteristics, however, some form of rough pattern compensation is desirable. If the noise power is assumed to be isotropic then the received noise power is proportional to the noise power flux for the polarization component in question and also the effective area of the antenna. Thus, for example, a purely horizontal antenna will respond only to horizontally polarized noise, etc. If we further assume that the effective area of the receiving antenna is proportional to the gain averaged over θ and ϕ we may write

$$N_v \propto \frac{\overline{G_v}}{\overline{G_v}+\overline{G_h}} P \qquad (2\text{-}34)$$

and

$$N_h \propto \frac{\overline{G_h}}{\overline{G_v}+\overline{G_h}} P \; (1-e^{-kz}) \qquad (2\text{-}35)$$

Where N_v is the received noise power density (vertical)

N_h is the received noise power density (horizontal)

$\bar{G}_v$ is the average gain for vertical polarization

$\bar{G}_v$ is the average gain for horizontal polarization

P is the noise power density from NWOMAP (corrected for frequency and bandwidth)

K is the user specified horizontal height power factor and

Z is the height of the terminal above ground in kilometers.

The total received noise power as used in the all mode power sum (Eq.1-1) is then simply

$$N_a = N_v + N_h. \qquad (2-36)$$

A default value of k=3.1 is employed in NUCOM/BREM. This value corresponds to a recovery in horizontal noise power of 99% at a height of 10λ (at 2 MHz) or 1.5km.

REFERENCES

1. A New Method for Predicting HF Ground Wave Attenuation over Inhomogeneous, Irregular Terrain, R. H. Ott, OT/ITS Research Report 7, Institute for Telecommunications Sciences, Boulder, Colorado, January 1971.

2. On the Numerical Solution of the Volterra Integral Equations, C. Wagner, J. Math. and Phys., 32, pp 289-401, 1953.

3. Suggestions for a Theory of Coastal Refraction, G. Grunberg, Phys. Rev., 63 (5 & 6), 1943.

4. Ground-Wave Propagation over an Inhomogeneous Smooth Earth. Part 2. Experimental Evidence and Practical Implications, G. Millington and G. Isted, PIEE (London), 97 (III), July 1950.

5. Mixed Path Ground Wave Propagation: 1. Short Distances, J. Wait, JNBS, 57 (1), July 1956, pp 1-15.

6. Propagation of Electromagnetic Waves Near a Coastline on a Flat Earth, R. F. Millar, Rad. Sci., 2 (3), March 1967, pp 261-286.

7. A Relation between the Sommerfeld Theory of Radio Propagation over a Flat Earth and the Theory of Refraction at a Straight Edge, H. G. Booker, and Q. C. Clemmow, PIEE (London), 96 (Part III), 1949, pp 53-64.

8. Propagation of Radio Waves past a Coast Line with a Gradual Change of Surface Impedance, J. R. Wait and K. P. Spies, IEEE T-AP, 14, September 1964, pp 570-575.

9. The Influence of the Ground and the Sea on Medium-Frequency Skywave Propagation, P. Knight, British Broadcasting Corp. Research Report RA-25, 1968.

10. Reception of Skywave Signals near a Coastline, J. B. Anderson, J. Res. NBS 67D (3), May-June 1963, pp 325-330.

11. Predicting Long-Term Operational Parameters of High-Frequency Skywave Telecommunication Systems, A. Barghausen, J. Finney and L. Proctor, ESSA Technical Report ERL 110-ITS 78, May 1969, and Addendum I, December 1970.

12. Methods of Applying Numerical Maps of Ionospheric Characteristics, W. B. Jones and R. M. Gallet, J. Res. NBS, 66D, November 1962, pp 649-662.

13. The Complex Impedance of the Earth's Surface at Radio Frequencies and its Measurement, E. Hanle, NTZ, 3, 1966.

14. The Surface Impedance Concept and the Structure of Radio Waves over the Real Earth, Z. Godzwiski, Proc. IEE (London), Monograph No. 434E, March 1961.

15. T. Kaliszewski, Modification and Extension of the CCIR Ground Wave Prediction Program for Rough Sea Pahts. 1976 International IEEE/APS Symposium and USNC/URSI Meeting, (Paper No. F5(9)). October 1976, Amherst, MA.

16. Impedance Boundary Conditions for Statistically Rough Surfaces, T. B. Senior, Appl. Sci. Res., 8B, pp 437-462, 1960.

17. Physical Oceanography, J. Neumann, and L. F. Pierson, Mc Graw-Hill, New York 1962.

18. J. Wait, Personal Communication.

19. Computer Program to Calculate Ground-wave Field Strength, M. Joachim; Y. Y. Mao; and W. Boyle; Telecommunications Journal, 40, pp 596-602, September 1973.

20. Some Electrical Characteristics of the Earth's Crust, D. Watt; F. S. Mathews; and E. L. Maxwell; Proc. IEEE, 51, pp 897-910, 1963.

21. MIL-A-9080 (USAF), Military Specification, Antennas, Liaison Communications Equipment, General Specification for Design of, 1954.

22. Aircraft Antennas, J. V. N. Granger; J. T. Bolljahn; Proc. IRE, 45, pp 533-558, May 1955.

23. Performance Specifications and Evaluation of Liaison Antennas, E. J. Moore, Stanford Res. Inst., Final Report, Task III, SRI Project 606, Contract AF 33(616)-83; November 1963.

24. Study of External Navigation Antennas on Lockheed Aircraft, A. R. Ellis, Airborne Instrumentation Labs, Mineola, N.Y., Report 726-II, August 1949.

25. Design Limitations on Aircraft Antenna Systems, J. V. N. Granger, Aero. Eng., 25, pp 82-87, May 1952.

26. Effect of Airframe Configuration on Low-Frequency Antenna Characteristics, C. M. Mobitzell, Tech. Rep. 38, Contract AF 19 (604) 266, Stanford Res. Inst., Stanford, CA, April 1953.

27. The measurements of Low-Frequency Aircraft Anenna Properties Using Electrostatic Techniques, J. T. Bolljahn, Tech. Rep., Contract AF 19 122078, Stanford Res. Inst., September 1954.

28. Electrical Small Antennas and the Low-Frequency Aircraft Antenna Problem, J. T. Bolljahn; R. F. Reese; Trans. IRE AP-1, pp 46-54, October 1953.

29. A New Approach to the Evaluation of HF Aircraft Antennas, J. F. Cline, and R. L. Tanner, Trans. IRE AP-4, pp 254-264, May 1962.

30. Factor of Merit for Aircraft Antenna Systems for the Frequency Range from 3 to 30 Mcs, E. J. Moore, Trans. IRE AP-3, pp 56-74, August 1952.

31. Systems Considerations in Aircraft Antenna Design, J. V. N. Granger, Trans. IRE AP-1, pp 1-12, December 1951.

32. Antenna Evaluation Methods, W. S. Lucke, Trans. IRE AP-6, pp. 251-254, July 1958.

33. Radiation Pattern Efficiencies of Some Suppressed HF Aircraft Antennas, J. Y. Wong, Trans. IRE Aero, and Nav. Elect., p 64, March 1958.

34. HF Suppressed Aerials for Aircraft, C. New and T. W. Sharpe AGARD Conference Proceedings No. 15, Radio Antennas for Aircraft and Aerospace Vehicles, Circa Publications, New York 1964.

35. Modification on KC-130F Aircraft for Operational Use of Airborne/Mobile Direct Air Support Center, D. L. Cooksey, Final Report No. NATC-WST-53R-70, Naval Air Test Center, Patuxent River, MD, April 1970.

36. H. F. Notch Aerials for Small Aircraft, C. G. Fitzpatrick and R. A. Burberry, Proceedings of the Conference on Aerospace Antenna, London, 1971; published by IEEE(UK).

37. The Notch Aerial and Some Applications to Aircraft Radio Installations, W. A. Johnson, IEE, 102, part IIIA, p 211, 1955.

38. Shunt and Notch-Fed H. F. Aircraft Antennas, R. L. Tanner, Trans. IRE AP-6, p 35, January 1958.

39. Current Distribution on Wing-Cap and Tail-Cap Antennas, I. Carswell, Tech. Report No. 43, Contract AF 19(604)-266, Standford Res. Inst. May 1954.

40. Boeing Aircraft Company, Seattle, Wash., private communication.

41. World Distribution and Characteristics of Atmospheric Radio Noise, CCIR Report 322, Geneva, 1964.

42. Numerical Representation of CCIR Report 322, High Frequency Atmospheric Radio Noise Data, D. L. Lucas, NBS Tech. Note No. 318, 1965.

43. C.C.I.R. Document Vl/17 (Federal Republic of Germany), Geneva, 1962. Measurement of Atmospheric Radio Noise.

44. Uber das Aussengerauch Kommerzieller Antennenanlagen, W. Kronjager and K. Vogt, NTZ, 12, 371, 1959.

45. The measurement of characteristics of terrestrial radio noise, V. Yalisley, URSI Special Report No. 7, Elsevier Publications, Amsterdam, 1962.

SECTION 3.0

SOFTWARE IMPLEMENTATION

Rather extensive modifications to certain parts of NUCOM II were necessary to implement the new features previously discussed. Approximately 1,100 new lines of code have been added to the RAYTRACE and COMEFF subprograms and several hundred more lines of existing code have been modified.

Because of the considerable complexity of the case stacking logic of the original NUCOM II code, every attempt was made to isolate the modifications required to calculate the nonionospheric modes in order to minimize the effects on the case control logic. The task of modifying NUCOM II has been simplified somewhat by its linear subprogram organizational structure which allowed us to limit the NUCOM/BREM modifications to the subprograms RAYTRACE and COMEFF without affecting the subprograms NATPAT, NUCEFMB, or ORDER.

All of the original NUCOM II features and outputs have been retained in NUCOM/BREM. The new nonionospheric calculations are made within the case control logic as if they were a special type of ionospheric ray path and the results of the nonionospheric analysis are presented independent of the original NUCOM II ionospheric analysis outputs.

Only the expanded antenna pattern elevation range feature directly enters into the ionospheric computations and then only to provide the user with the option of entering tabular pattern gain values for elevation angles as high as 90° instead of the maximum of 40° in NUCOM II. Computations using these high angle pattern

gains for ionospheric rays proceed as in NUCOM II.

The new or modified subroutines in RAYTRACE and COMEFF are heavily commented in the source code and subroutine structure has been kept as simple and straightforward as possible consistent with the constraints imposed by the preexisting code. The remainder of this Section details the software implementation of NUCOM/BREM; detailed descriptions of the unmodified code will be found in Reference 1 of Section 1.

NUCOM/BREM is coded in IBM FORTRAN IV G for the IBM System 370/145. The original IBM code is derived from the GE TEMPO version described in Reference 2 of Section 1.

3.1 Overview of NUCOM/BREM Software Modifications

The basic strategy in the modification of NUCOM II to include nonionospheric propagation modes is shown in Figure 3-1. Upon completion of ionospheric ray processing in the subroutine RAYTRACE of the last propagating ray for a case and frequency the main program flow is diverted to the control subroutine BREM10. It in turn calls other subroutines to calculate the power densities for the nonionospheric rays after calculating effective ground parameters where necessary. The nonionospheric path component power densities are flagged as "special" but otherwise are written onto unit 7 along with the normal ionospheric ray components for processing by the subroutine COMEFF. This approach results in minimal disruption of the case stacking logic and case control flow.

The "special" flagged components read from unit 7 by the subroutine COMEFF are processed separately to yield a total nonionospheric received compensated power density which in turn becomes a term in all mode signal to noise power calculation as shown in Figure 3-2. The subroutine COMEFF has been modified to read in extended elevation range antenna pattern tables for both vertical and horizontal polarization components and values interpolated from these tables are applied to each of the nonionospheric "special" components passed from unit 7 along with the user supplied power density correction to yield the compensated power density. The power density for each received component is combined in the nonionospheric power flux calculation in the subroutine COMEFF. After correcting the vertical noise

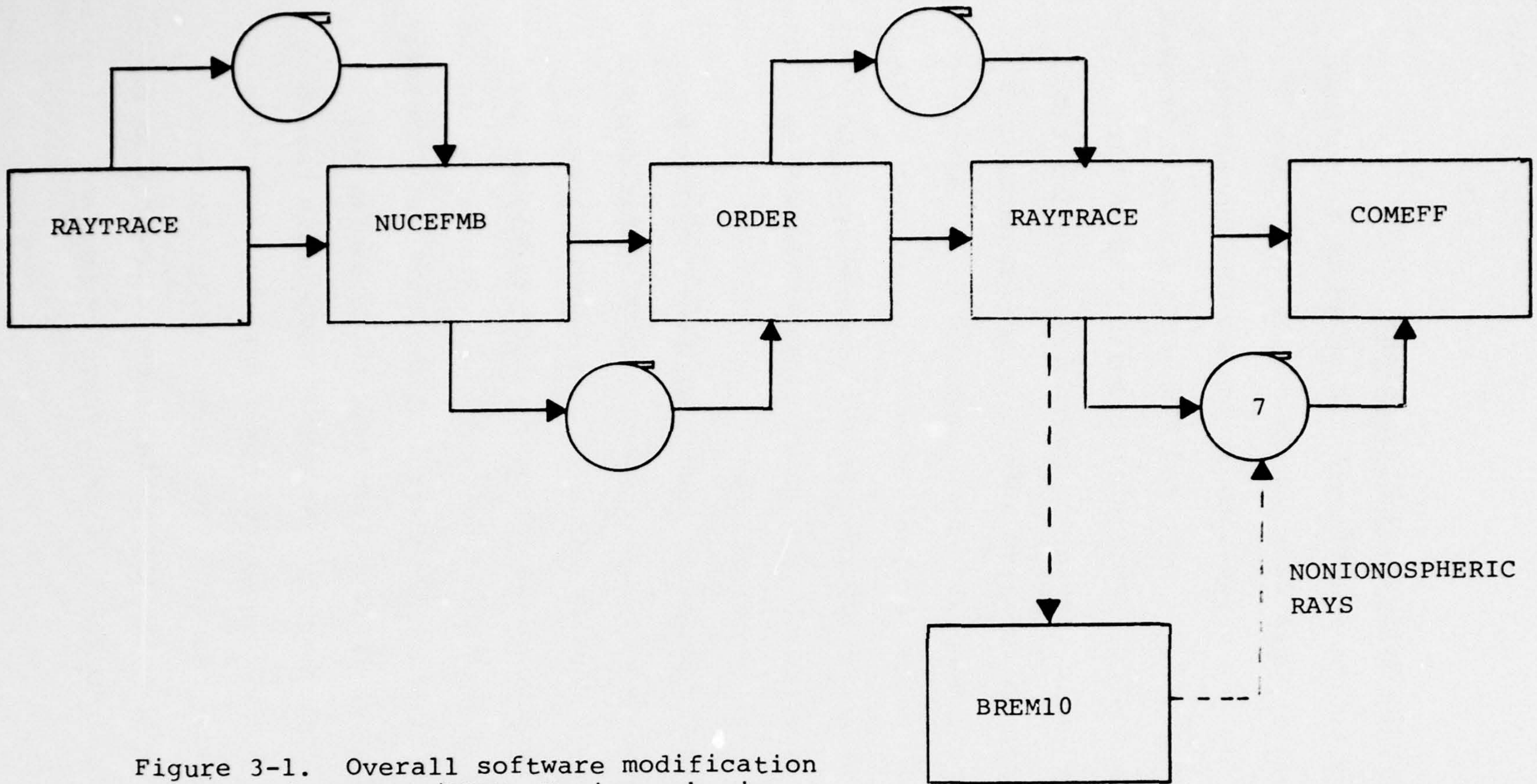


Figure 3-1. Overall software modification strategy for NUCOM/BREM. Nonionospheric propagation modes are calculated by BREM called by RAYTRACE; nonionospheric rays are written onto temporary storage as "special" ionospheric rays and input by COMEFF for power flux summation.

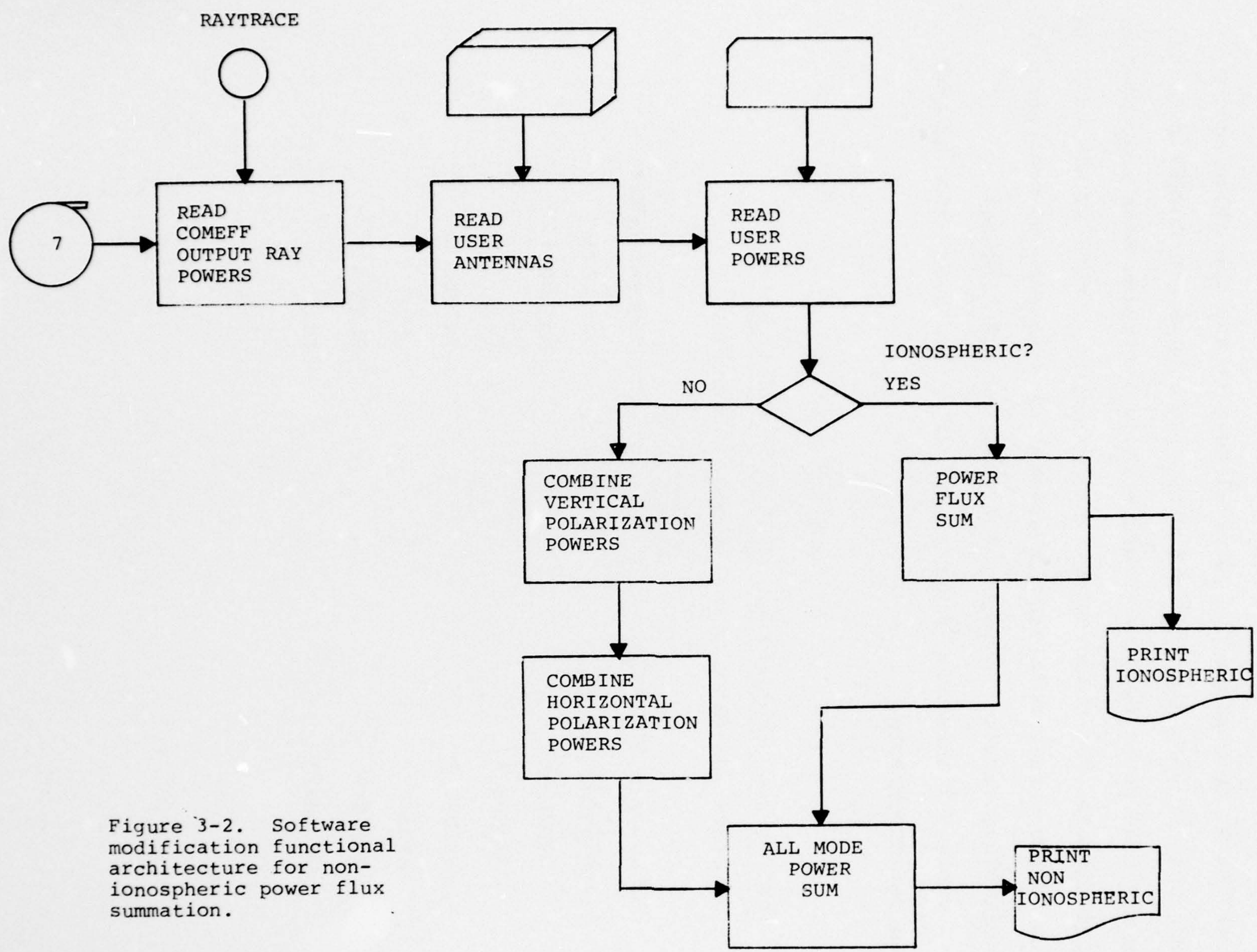


Figure 3-2. Software modification functional architecture for non-ionospheric power flux summation.

figure from the ITS Blue Binary Tape processed in the subroutine in NATPAT to compensate for terminal heights and the polarization ratio for the user supplied patterns, the subprogram COMEFF computes the all mode power density to noise ratio including both ionospheric and nonionospheric components. The subprogram COMEFF prints both the normal ionospheric mode outputs as well as a variety of nonionospheric intermediate results in addition to all the mode figures.

Table 3-1 shows the subroutines which have been added or modified for NUCOM/BREM.

Table 3-1

Subroutines Affected by NUCOM/BREM Modification

Asterisk indicates a wholly new subroutine.

Subprogram RAYTRACE	Subprogram COMEFF
ASGEPS *	BLK DATA
BREM1O *	CPOWER *
FSGEPS *	F1
GRNDWV *	INITLC
MDHNKL *	ONE
RAYTRA	RDATNA *
RFLXRA *	READ

3.2 Modifications to Subprogram RAYTRACE

The modifications to the subprogram RAYTRACE are concerned only with the calculation of nonionospheric mode signal powers. Aside from the addition of a new user input card to describe the type of groundwave treatment required (i.e., Suda or Millington) and to provide user sophisticated ground and sea state parameters, the modification to the subroutine RAYTRACE are strictly computational in nature. Table 3-2 summarizes the nature of the changes to preexisting subroutines and the function of the new subroutines. The overall flowchart of Figure 3-3 shows the effects of the NUCOM/BREM modification to the subprogram flow.

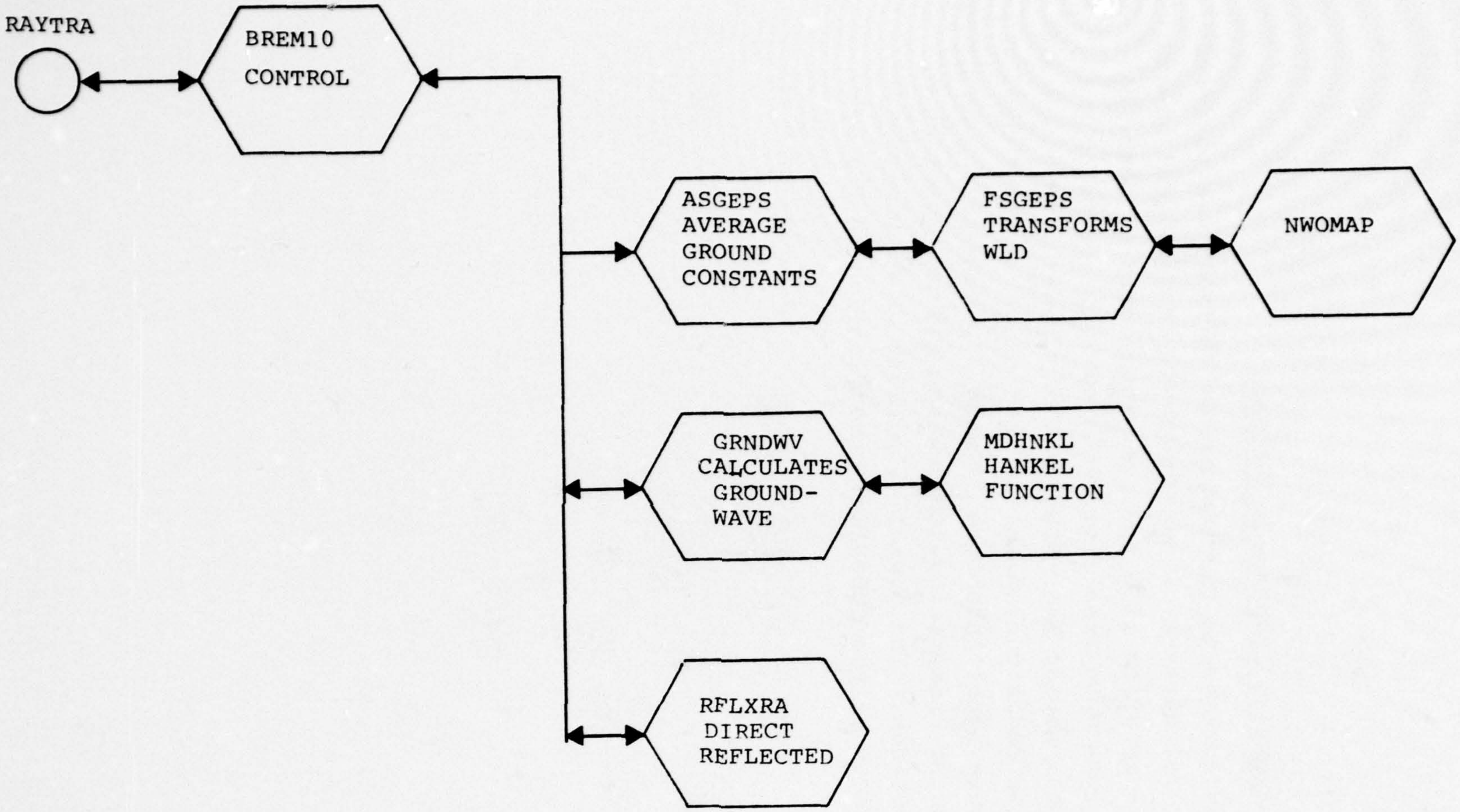


Figure 3-3. Subroutine calling flow for subprogram RAYTRACE calls to BREM10 for nonionospheric calculations

TABLE 3-2

New or modified subroutines in subprogram RAYTRACE

Subroutine	Changes/Description
ASGEPS	Did not previously exist. Calculates the effective ground constants at selected points along signal path using NWOMAP data andsea state corrections.
BREM10	Did not previously exist. This is the control subroutine for calculation of non-ionospheric signal powers. Determines the type of signal mode to be processed and prints intermediate results for user guidance.
FSGEPS	Did not previously exist. Transforms the dimensionless variable GAMMA returned by NWOMAP to effective ground parameters and applies sea state corrections for effective equivalent conductivity.
GRNDWV	Did not previously exist. Calculates ground-wave field strength for both polarization components using Bremmer - van der Pol equations. Calculates height gains using modified Hankel function routine MDHNKL.
MDHNKL	Did not previously exist. Calculates modified Hankel function of the first kind and order one-third for the evaluation of height gains for elevated terminals.
RAYTRA	Main line RAYTRACE control subroutine; one line modified to call BREM10 for nonionospheric power calculations.
RFLXRA	Did not previously exist. Calculates the reflected ray powers for elevated terminals using Fresnel and defocussing losses plus free space losses.

3.2.1 Subroutine ASGEPS

Description

Subroutine ASGEPS determines the effective ground constants at various points along the great circle signal path using NWOMAP and calculates the Suda average values including the effects of sea state disturbances if any. Given a pair of geographical end point coordinates XLOC and YLOC, the great circle bearing DIR, and step size SEGSIZE, ASGEPS uses the subroutine COOR to determine the geographical coordinates for each of ISGCNT segments. These coordinates are passed to NWOMAP and the returned dimensionless variable GAMMA is corrected to sigma and epsilon by FSGEPS. If a nonzero wind velocity WVEL is specified the correction is made in FSGEPS. The resulting averages values SOUT and EOUT are returned by ASGEPS. A flow chart for ASGEPS is presented in Figure 3-4.

Call Statement

CALL ASGEPS (SEGSIZ, ISGENT, XLOC, YLOC, DIR, WVEL, SOUT, EOUT)

Arguments

SYMBOL	TYPE	DESCRIPTION
SEGSIZ	Input	Great circle distance from end point, km
ISGCNT	Input	Number of segments of length SEGSIZ
XLOC	Input	Latitude of start point
YLOC	Input	Longitude of start point
DIR	Input	Great circle bearing of path from start point

SYMBOL	TYPE	DESCRIPTION
WVEL	Input	Wind velocity, km/sec.
SOUT	Out	Effective sigma
EOUT	Out	Effective epsilon

Common Storage Arguments Used

ERTHR, Pl, RAD, DEG, PlBY2, TWOPl, REFIND, FREQ, BON, LONG, LAT, GAMMA, GMT, IO

Internal Subroutines Required

NWOMAP, COOR, FSGEPS

Number of Locations Required

940_{10}

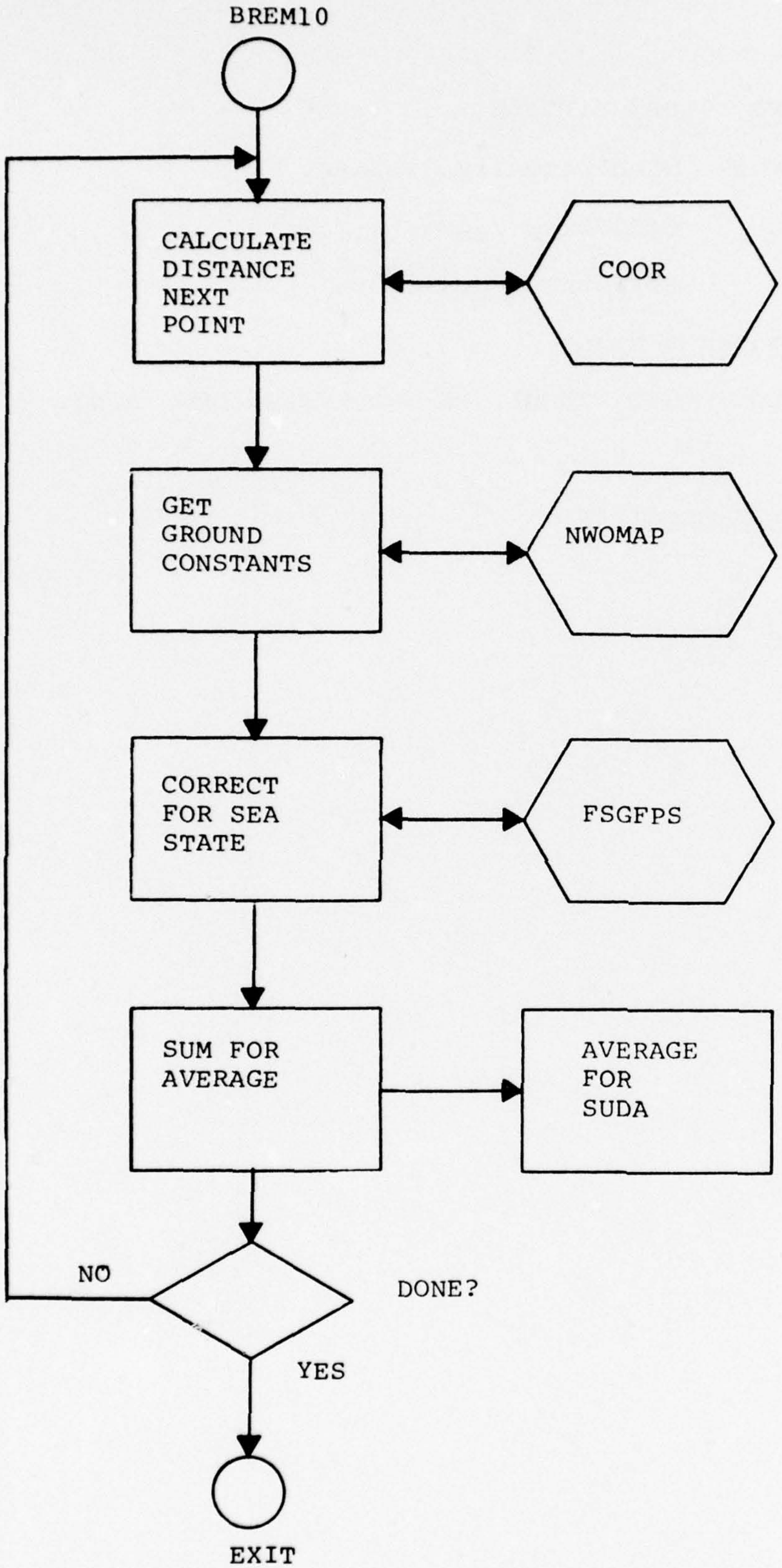


Figure 3-4. Flowchart for subroutine AGSEPS

3.2.2 Subroutine BREM10

Description

Subroutine BREM10 is the control program for the calculation of nonionospheric signal components in RAYTRACE. Given the coordinates and heights of the terminals BREM10 calculates the nonionospheric path geometry in order to determine computational types (i.e., line-of-sight, groundwave, reflected ray) to be computed. User supplied inputs for nonionospheric modes are read. If ground constants are required and are not user supplied BREM10 initiates calculation of the appropriate Suda or Millington values with corrections for sea state if necessary. The uncorrected field strengths for all relevant modes are calculated and corrected to unity power density. Computed nonionospheric mode powers and necessary elevation angles are written for COMEFF. BREM10 also prints relevant nonionospheric mode parameters including the segment values of ground constants and resulting effective homogeneous values for Suda or Millington treatments. A flow chart for BREM10 is presented in Figure 3-5.

Call Statement

CALL BREM10 (PLNGT, TLATD, TLONGD, RLATD, RLONGD, BER)

Arguments

SYMBOL	TYPE	DESCRIPTION
PLNGT	Input	Path length along great circle in kilometers
TLATD	Input	Transmitter latitude
TLONGD	Input	Transmitter longitude

SYMBOL	TYPE	DESCRIPTION
RLATD	Input	Receiver latitude
RLONGD	Input	Receiver longitude
BER	Input	Great circle bearing

User Supplied Input Common

SYMBOL	FORMAT	DESCRIPTION
THT	F10.3	Transmitter height, meters
RHT	F10.3	Receiver height, meters
SIGMA	F10.3	User supplied conductivity, Mho/m
EPSILON	F10.3	User supplied, dielectric constant, relative units
WNDVEL	F10.3	User supplied mean wind velocity, meters/second.
NSEGS	I5	Number of segments for Suda segmentation
MPTS	I5	Number of segments for Millington segmentation
FACHNZ	F10.3	User supplied horizontal noise height factor.

Output Variables to COMEFF

SYMBOL	FORMAT	DESCRIPTION
TTT	F6.0	Time (s)
FACHNZ	F10.3	Horizontal noise height correction factor
FREQ	F6.2	Frequency, MHz
BETA	F6.2	Last ionospheric transmitter beta (dummy)
DMY2	F6.2	Dummy
DMY3	F7.1	Dummy
THT	F7.1	Transmitter height, meters
RHT	F9.1	Receiver height, meters
RNOYS (IFCT)	F7.1	Noise power density

SYMBOL	FORMAT	DESCRIPTION
JHOUR	I5	Hour (GMT)
DMY6	F10.5	Dummy
DBV	G12.6	Power density (dBW), vertical component
DBH	G12.6	Power density (dBW), horizontal component
DBL	G12.6	Power density (dBW) for LOS component
TBD	F10.3	Angle of direct ray at transmitter
TBR	F10.3	Angle of reflected ray at transmitter
RBD	F10.3	Angle of direct ray at receiver
RBR	F10.3	Angle of reflected ray at receiver.

Common Storage Arguments Used

EARTHR, P1, RAD, DEG, P1BY2, TWOP1, REFIND, FREQ/BON/LONG, LAT, GAMMA, GMT, 10, /GWAVE/SIGMA, EPSILON, THT, RHT, DKM, DLOS, THETA, LAMBDA, J

/PO/ JK, KL, IFCT, GR LOSS, ALA1, ALA2, LLF, IHRC, P200, DB, HTCAL, JHOUR, RNOYS(80), FHNAME(12), BETA, TTT.

Internal Subroutines Used

RFLXRA, GRNDWV, ASGEPS, COOR

Number of Storage Locations Required

4126_{10}

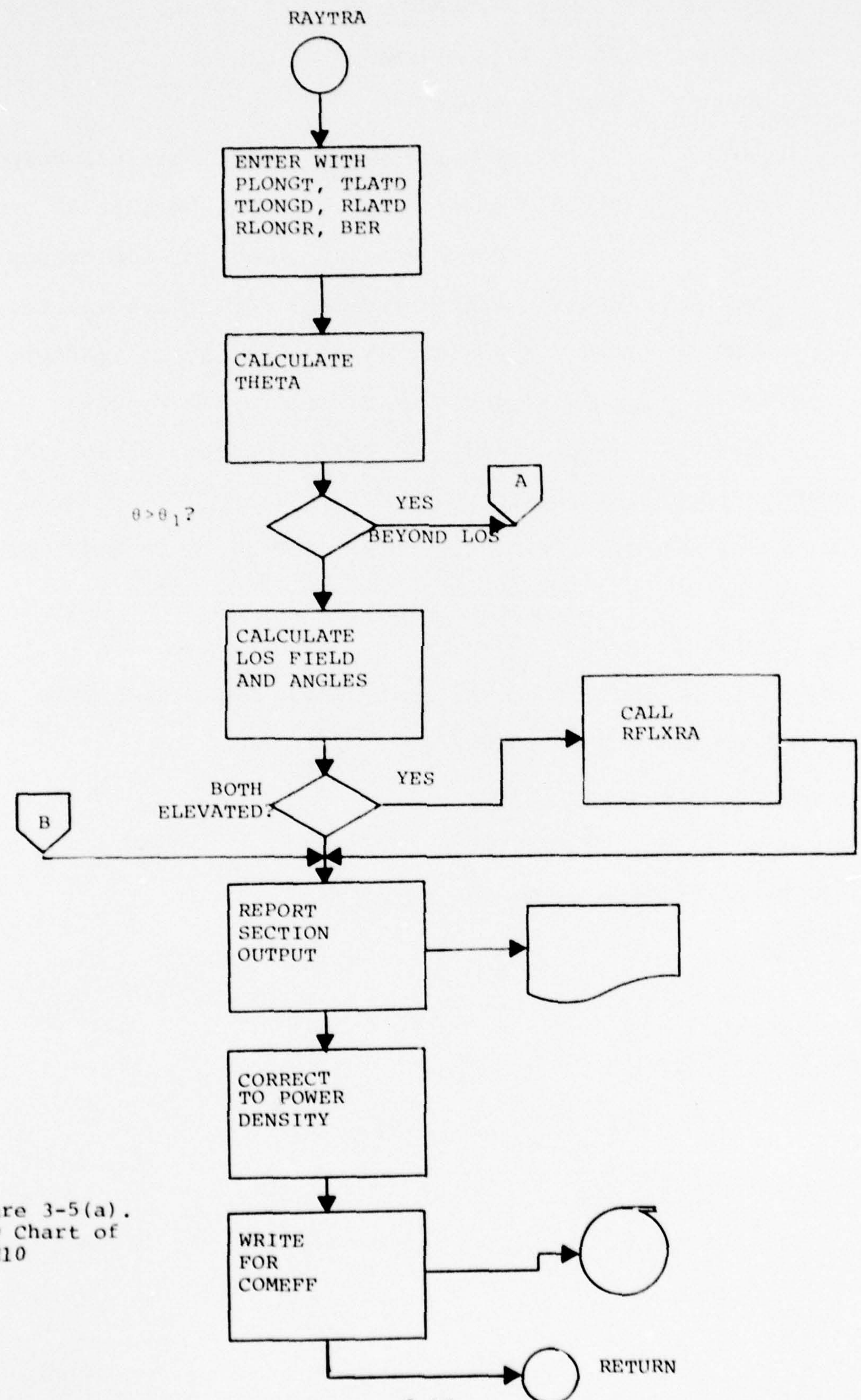


Figure 3-5(a). Flow Chart of BREM10

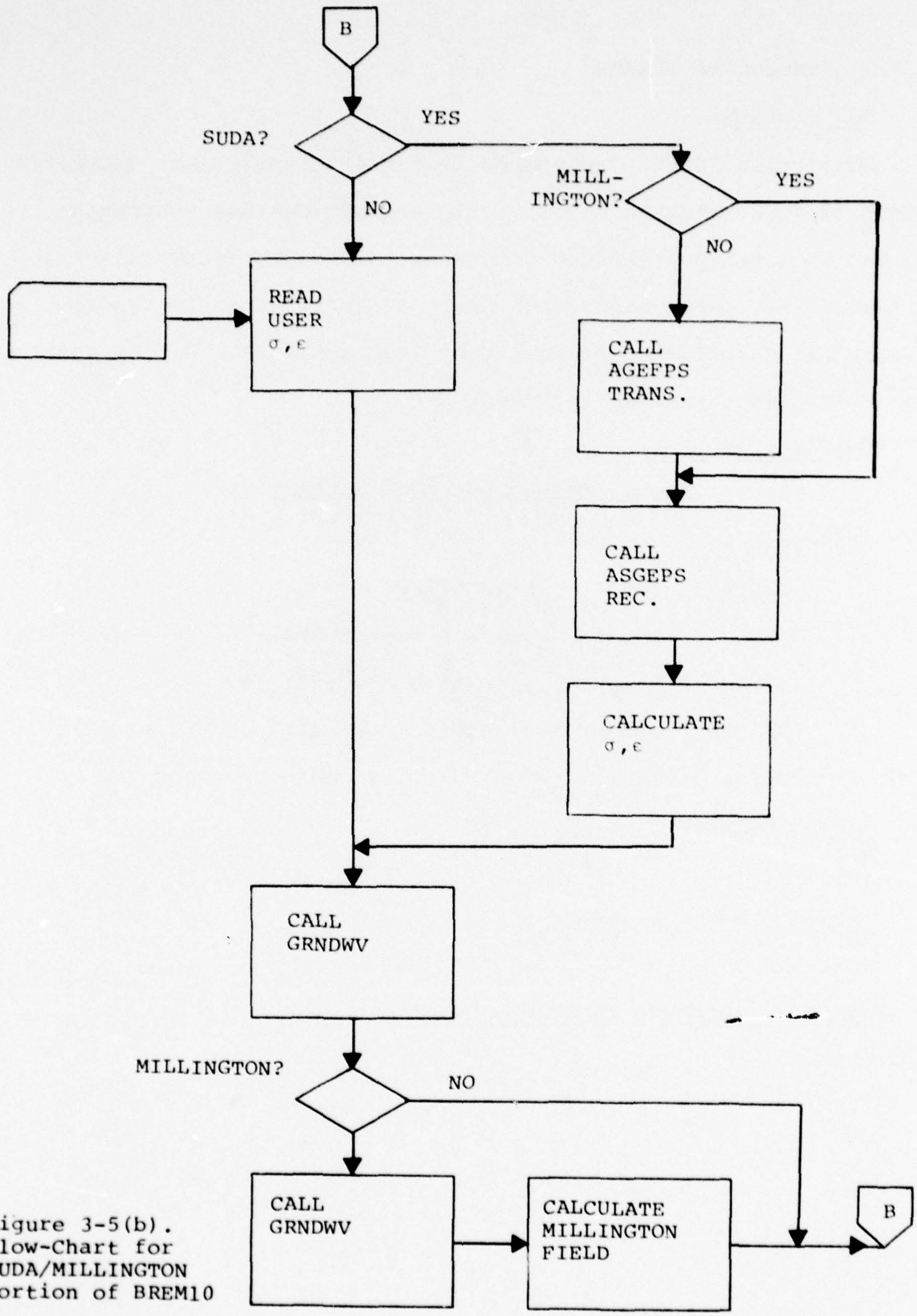


Figure 3-5(b). Flow-Chart for SUDA/MILLINGTON portion of BREM10

3.2.3 Subroutine FSGEPS

Description

Subroutine FSGEPS transforms from the dimensionless quantity GAMMA (= WLD) returned by the world ground constant subroutine NWOMAP to sigma and epsilon according to the algorithms described in Table 2-2. User input wind velocity corrections to conductivity are calculated per Equations 2-27 and 2-28. A flow chart for FSGEPS is presented in Figure 3-6.

Call Statement

CALL FSGEPS (GAMMA, SIGMA, EPSILON, WNDVEL)

Arguments

SYMBOL	INPUT	DESCRIPTION
GAMMA	Input	Returned from NWOMAP
SIGMA	Output	Calculated conductivity
EPSILON	Output	Calculated dielectric constant
WNDVEL	Input	Wind velocity, meters/second

Common Storage Arguments Used

None.

Internal Subroutines Used

None.

Number of Storage Locations Used

654_{10}

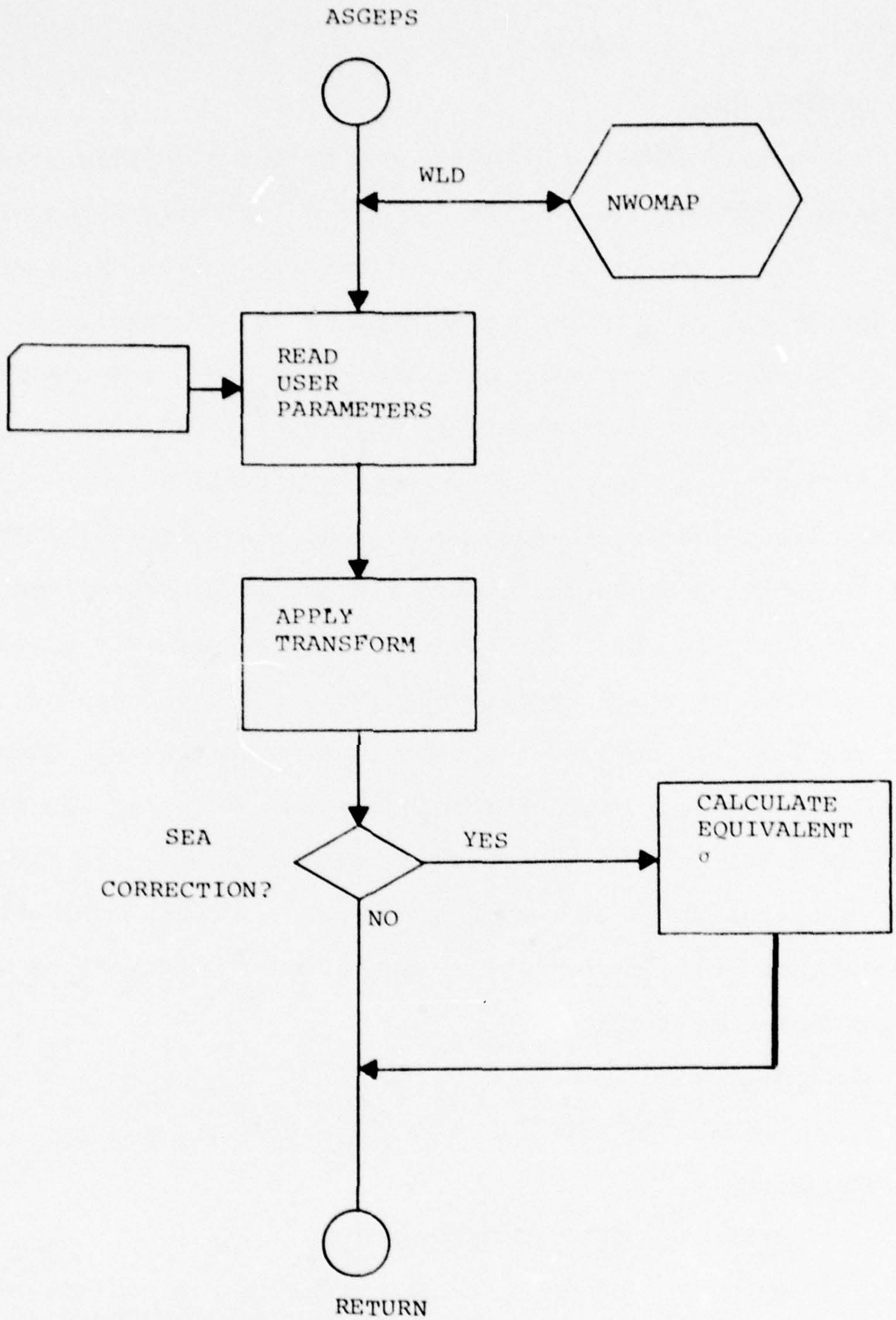


Figure 3-6. Flowchart of subroutine FSGEPS

3.2.4 Subroutine GRNDWV

Description

Subroutine GRNDWV calculates the groundwave field strength using the Bremmer- van der Pol equations as described in Section 2.1.1. The input switch POLAR determines whether the vertical or horizontal polarization component is to be calculated. The input parameters in COMMON describe the geometry of the path in terms of DKM, the path length in kilometers; THT, the transmitter elevation in meters; RHT, the receiver elevation in meters; SIGMA, the effective homogeneous ground conductivity; EPSLON, the effective homogeneous ground dielectric constant; and FREQ, the frequency in MHz. The output of GRNDWV consists of the arguments EV and EH which are the receiver site uncompensated fields the vertical and horizontal components respectively. Computation proceeds in a straightforward manner using the equations of Section 2.1.1 and the modified Hankel function of the first kind and order one-third as returned from the subroutine MDHNKL for height gain evaluation. A flow chart for the subroutine GRNDWV is presented in Figure 3-7.

Call Statement

CALL GRNDWV (EH, EV)

Arguments

SYMBOL	TYPE	DESCRIPTION
EH	Output	Electric field strength, rms, dB above 1μV/m, horizontal component
EV	Output	Electric field strength, rms, dB above 1μV/m, vertical component

Input Variables through Common

SYMBOL	TYPE	DESCRIPTION
SIGMA	Input	Effective ground conductivity
EPSLON	Input	Effective ground dielectric constant
THT	Input	Transmitter height, meters
RHT	Input	Receiver height, meters
DKM	Input	Path length on surface, kilometers
DLOS	Input	Line-of-sight distance, kilometers
THETA	Input	Central earth angle subtended by path, radians
LAMBDA	Input	Wavelength, meters

Internal Subroutines Used

MDHNKL

Number of Storage Locations Used

9412_{10}

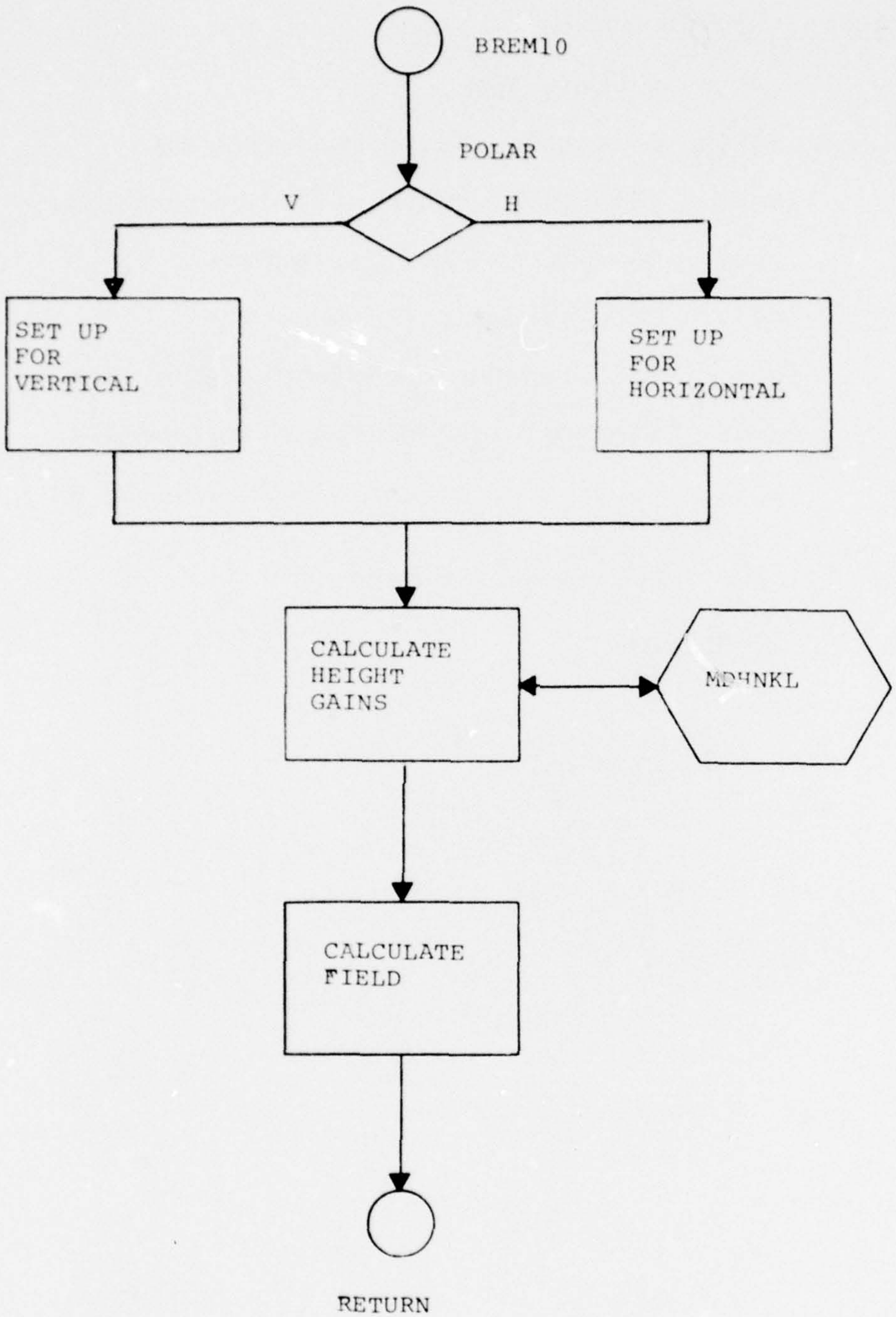


Figure 3-7. Flowchart of subroutine GRNDWV.

3.2.5 Subroutine MDHNKL

Description

The subroutine MDHNKL calculates the modified Hankel function of the first kind and order one-third, $H_{1/3}^{(1)}$, as described in Reference 5 of Section 1. The subroutine MDHNKL is called by the subroutine GRNDWV as part of the evaluation of the transmitter and/or receiver height gain functions given in Equations 2-8 through 2-13. A flow chart for this subroutine is presented in Figure 3-8.

Call Statement

CALL MDHNKL (Z, H1, H2, H1PRME, H2PRME).

Arguments

SYMBOL	TYPE	DESCRIPTION
Z	Input	Input argument to Hankel function
H1	Output	First Hankel solution
H2	Output	Second Hankel solution
H1PRIME	Output	Derivative of first Hankel
H2PRIME	Output	Derivative of second Hankel solution

(Note: All arguments double precision complex)

Internal Subroutines Used

None.

Number of Storage Locations Used

5684_{10}

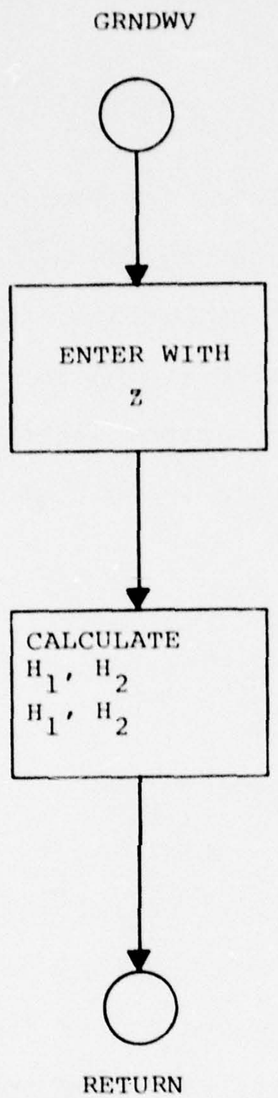


Figure 3-8. Flowchart of subroutine MDHNKL.

3.2.6 Subroutine RAYTRA

Description

RAYTRA is the MAIN subroutine for the subprogram RAYTRACE. The only modification to RAYTRA is the insertion of a one-line call to the subroutine BREM10 to initiate calculation of non-ionospheric comments. This call is made following computation of the last ionospheric ray for a case frequency time. This change is line 36670 RAYTRA.

3.2.7 Subroutine RFLXRA

Description

The subroutine RFLXRA calculates the field strength of the ground reflected ray when two elevated terminals are within line-of-sight. The computations follow directly from Equations 2-18 through 2-25 of Section 2.1.3 and Figure 2-2(c). Three distinct sources of loss are evaluated by RFLXRA: the free space loss, the Fresnel reflection loss, and the defocussing loss as defined by Equation 2-19. If the user has supplied the ground constants for the reflection point via card input, computation begins directly. Otherwise, the subroutines NWOMAP and FSGEPS are called to determine the ground parameters at the reflection point. The Fresnel angle of incidence, the geographical coordinate of the reflection point, and the angles τ_4 and τ_2 (TAU4 and TAU2) of Figure 2-3(c) then evaluated. The ground constants are corrected for wind effects if any by FSGEPS, and the resulting effective values used in the computation of first the horizontal and then vertical reflection coefficients and received uncompensated fields. A flowchart of RFLXRA is presented in Figure 3-9.

Call Statement

CALL RFLXRA (TRANSX, TRANSY, BER, WINDVEL, TBD, TBR, RBD, RBR, EH, EV)

Arguments.

Symbol	Type	Description
TRANSX	INPUT	Transmitter latitude
TRANSY	INPUT	Transmitter longitude
BER	INPUT	Great circle bearing to receiver
WNDVEL	INPUT	Wind velocity for sea state correction, meters/second.
TBD	OUTPUT	Direct ray angle at transmitter measured relative to zenith.
TBR	OUTPUT	Reflected ray angle at transmitter measured relative to zenith.
RBD	OUTPUT	Direct ray angle at receiver measured relative to zenith.
RBR	OUTPUT	Reflected ray angle at receiver measured relative to zenith.
EH	OUTPUT	Uncompensated field strength for horizontal polarization component, μV/m.
EV	OUTPUT	Uncompensated field strength for vertical polarization component, μV/m.

Common Storage Arguments Used.

ER, THR, PI, RAD, DEG, PIBY2, TWOPI, REFIND, FMC
/BON/YLOC, XLOC, GAMMA, GMT, IO
IGWAVE/SIGMA, EPSILON, THT, RHT, DKM,
DLOS, THETA, LAMBDA, J

Internal Subroutines Used.

COOR, NWOMAP, FSGEPS

Number of Storage Locations Used.

2992_{10}

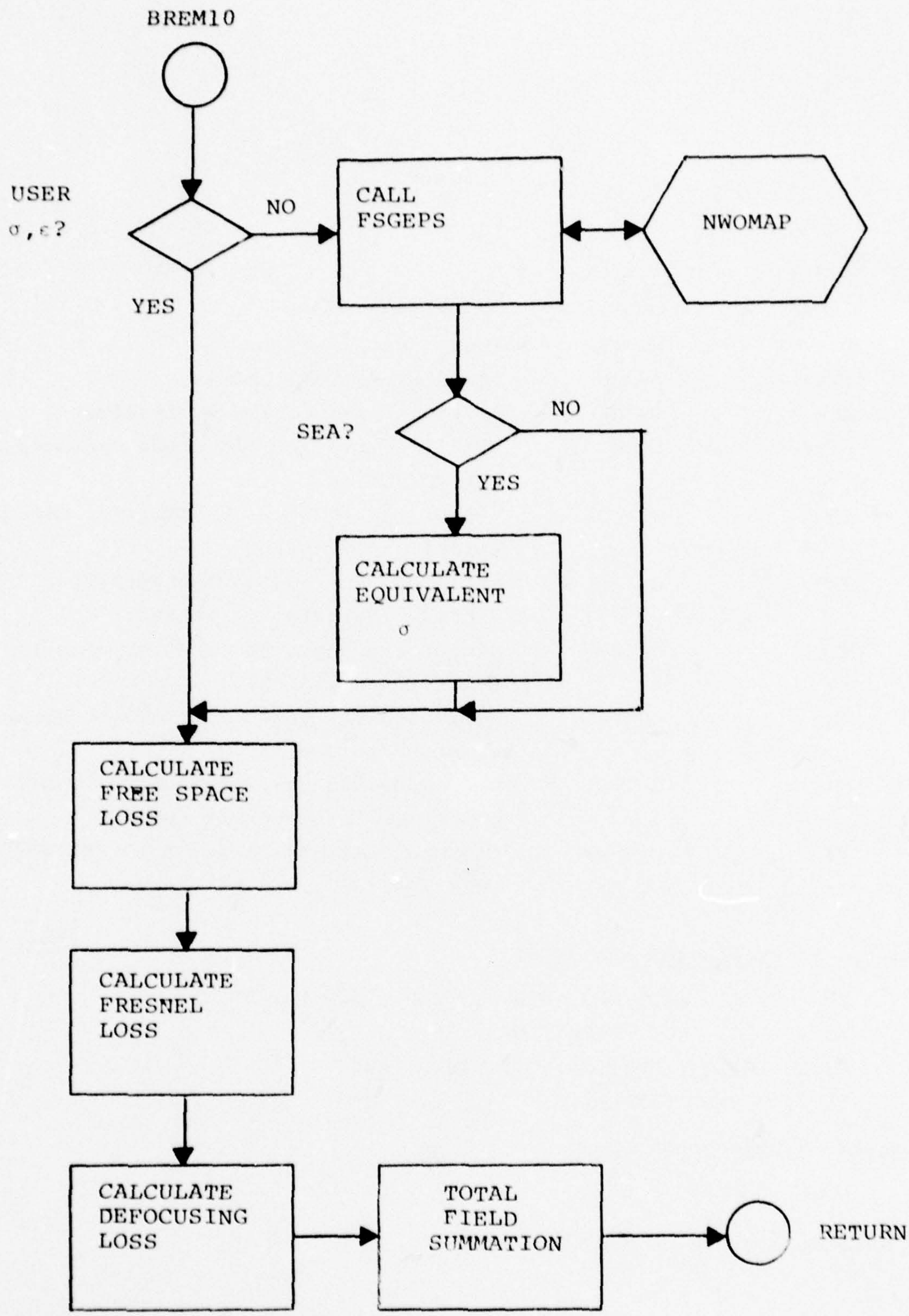


Figure 3-9. Flowchart of subroutine RFLXRA

3.3 Modifications to Subprogram COMEFF

The modifications to COMEFF fall into two broad areas: those concerned with incorporation of the nonionospheric components into the all mode power sum, and those concerned with the significantly expanded input antenna capability of NUCOM/BREM. Table 3-3 summarizes the changes to preexisting subroutines and the functions of the new subroutines. The overall flowchart of Figure 3-10 summarizes the effects of the NUCOM/BREM modification to such program flow.

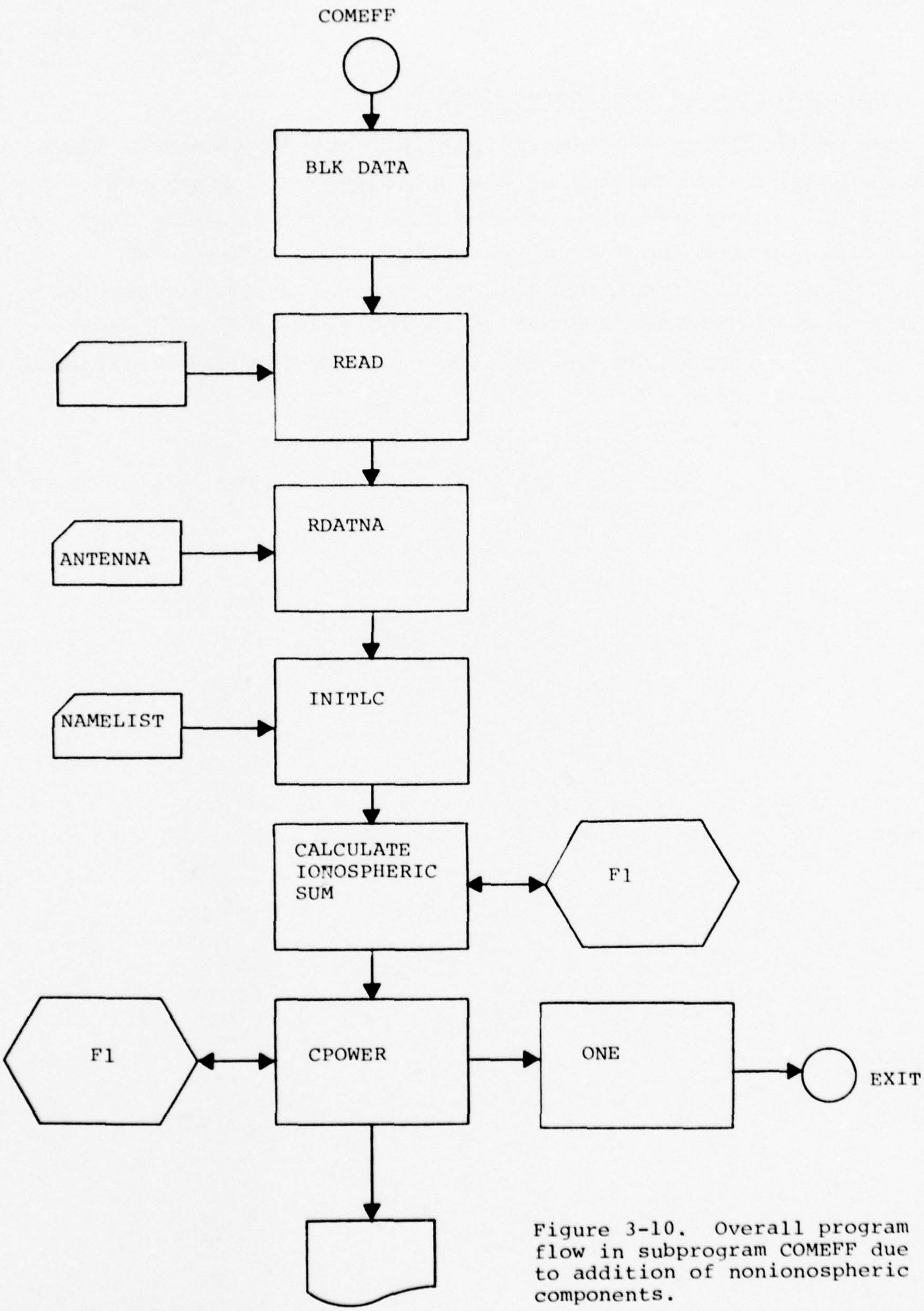


Figure 3-10. Overall program flow in subprogram COMEFF due to addition of nonionospheric components.

TABLE 3-3

New of modified subroutines in subprogram COMEFF

Subroutine	Changes/Descriptions
CPOWER	Did not previously exist. All calculations resulting from nonionospheric modes in RAYTRACE are handled in this subroutine.
Fl (FUNCTION)	Interpolates antenna gain values (or returns 1.0 for isotropic). Substantially rewritten to permit user specified antenna patterns to $\pm 90^{\circ}$, to permit distinct vertical and horizontal polarization patterns, to reduce restrictions on number of frequencies input, and to permit transmitter and receiver patterns to have different ranges.
INITLC	Rewritten to permit NAMELIST input of user specified parameters: transmitter antenna pattern range, receiver antenna pattern range, number of frequencies supplied, antenna file number. The antenna pattern input function is now contained in a new subroutine RDATNA.
ONE	Rewritten slightly to permit accumulation of ionospheric ray power for CPOWER.
RDATNA	New subroutines to permit increased antenna input features.
READ	New input card type and call to CPOWER to permit processing of nonionospheric components.
BLK DATA	Significantly expanded to accomodate new data structures.

3.3.1 BLK DATA

Description

BLK DATA establishes dimensions and data types for the new data structure in NUCOM/BREM. A flowchart of BLK DATA is presented in Figure 3-10.

Call Statement

Not Applicable

Arguments

Not Applicable

Common Storage Arguments Used

/DATA/C2, FOURPI, EFPL, TABLFR(15), 1 DUMM, MAX, IDEBUG
/SPPASS/NOFREQ, INPFIL, VGTOT, RGTOT, HGTOT
/SAVSIG/HIRAY P, IFLAG
/SWITCH/KSW1, KSW2, JF, 1 BETA, JCARD, NEWANT
/XLIT/AST, LIN, BLANK, STAR

Internal Subroutine Used

NONE

Storage Locations Used

238_{10}

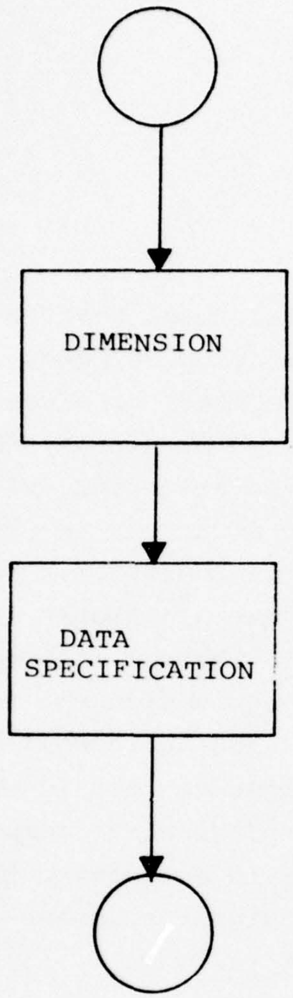


Figure 3-11. Flowchart of block data subprogram BLK DATA.

3.3.2 Subroutine CPOWER

Description

The subroutine CPOWER calculates the total received compensated power of each polarization type and the all mode power sum. Using input data from file JF, CPOWER calculates the total received signal power compensated for antenna gain and actual power density for direct, reflected, and groundwave rays of each polarization. Each compensated raytype power including the ionospheric power sum is then summed to provide the all mode signal power sum. The vertically polarized ionospheric noise power RNOIS from the ITS data is NWOMAP is corrected to compensate for the user-supplied noise height factor FACHNZ and the relative antenna pattern factor CONHNZ to provide the received horizontal noise power F_H. The power sum of the horizontal and vertical noise power densities is then used to compute the all mode signal to noise ratio. A considerable number of intermediate computations are printed to provide guidance to the user in evaluating the parameters which contribute to the final all mode signal to noise ratio. A flowchart of CPOWER is presented in Figure 3-12.

Call Statement

CALL CPOWER (P, TP, ALPSUM)

Arguments

Symbol	Type	Description
P	INPUT	User specified power density, W/Hz
TP	OUTPUT	Total received nonionospheric signal power, dBW
ALPSUM	OUTPUT	All mode power sum, dBW

Common Arguments Used

T, FACHNZ, FR, DT, DR, RHT, VNOIZ, THT

/SWITCH/KSW1, KSW2, 5F, IBETA

/SAVSIG/HIRAYP

/ANTDAT/TABL1V(181,8), TABL LH (181,8),
TABL2V(181,8), TABL2H (181,8)

/SPPASS/IANT, ANTFIL, UGTOT, RGTOT, HGTOT

Internal Subroutines Used

None

Number of Storage Locations Used

3404_{10}

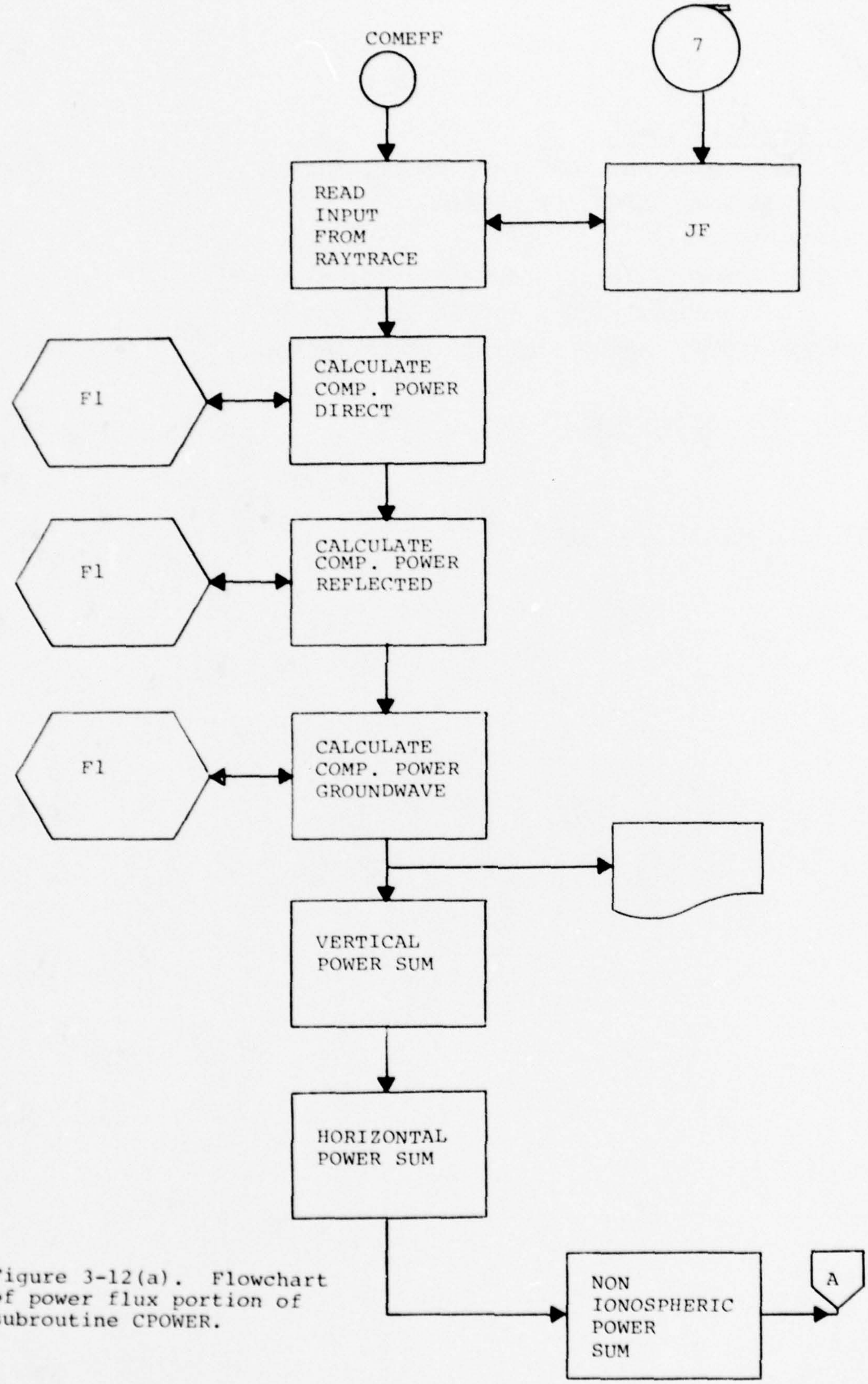


Figure 3-12(a). Flowchart of power flux portion of subroutine CPOWER.

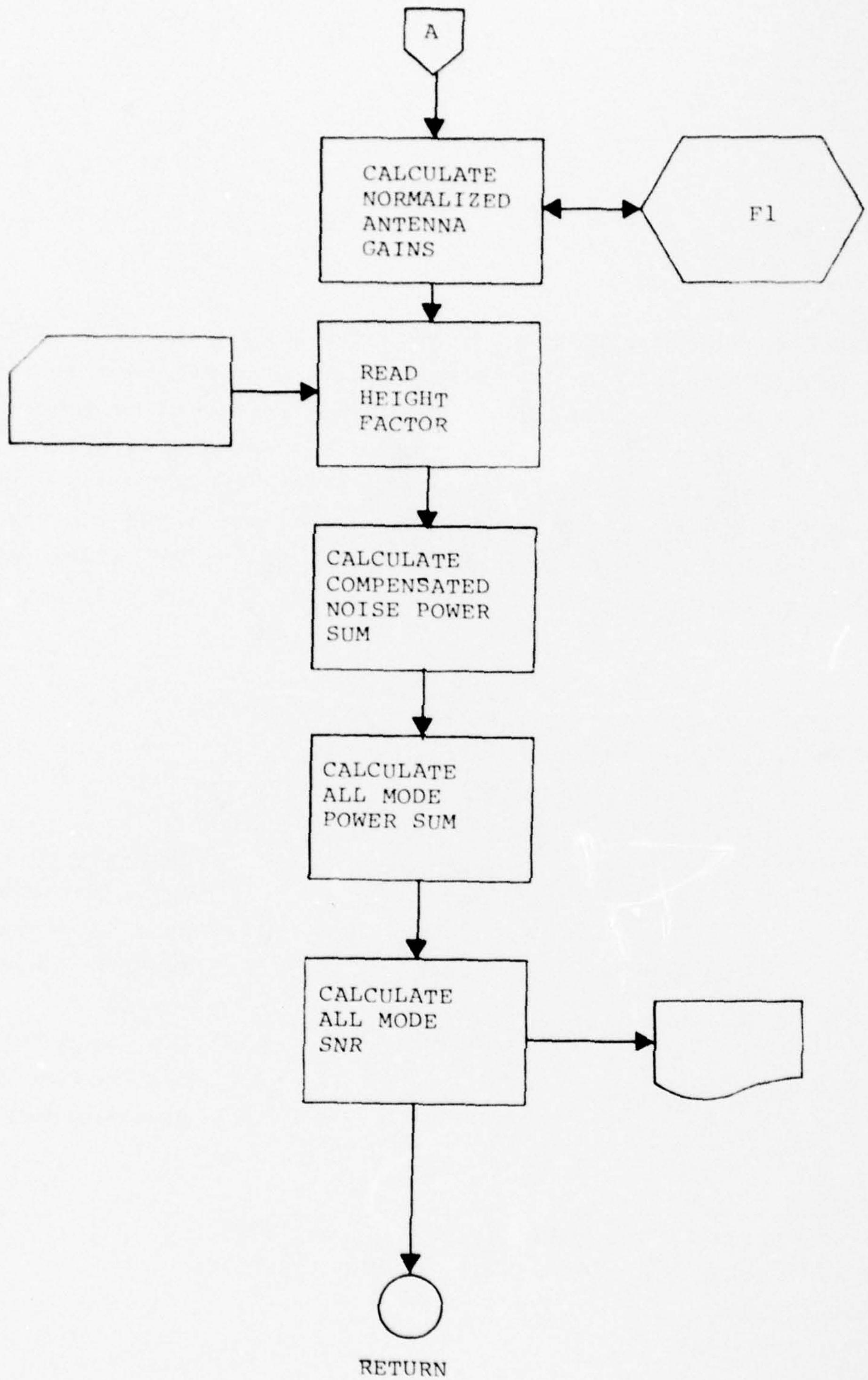


Figure 3-12(b). Flowchart of noise and SNR portion of subroutine CPOWER.

3.3.3 Function F1

Description

The function F1 provides the antenna gain for a particular angle, frequency, and polarization type. If no antenna patterns have been supplied or if the angle in question is outside the specifed range of antenna data, an isotropic gain is assumed and a warning is printed for the user. Interpolation on frequency and angle is performed with power ratios (not in dB) assuming linearity. The user input antenna patterns are printed in tabular format for energy 1 or 10 values depending upon the user parameter PRNT. A flowchart for the function F1 is given in Figure 3-13.

Call Statement

FUNCTION (X, TABL, NPAT)

Arguments

Symbol	Type	Description
X	INPUT	Angle for which gain is required
TABL	INPUT	Antenna table vector
NPAT	INPUT	Distinguishes between transmitter and receiver tables

Common Arguments Used

PT(1000, 3), A(1000), PHASET (1000), TAUS(1000), MODE (60), TIME (30), FREQ (30), SIGTAU (20,20), SIGNOI (20,20)

```
/ANTDAT/ TABL1V (181,8), TABL1H (181,8)
         TABL2V (181,8) TABL2H (181, 8)
         MXANGL (2), MNANGL(2), KRXN(2),
         NANGLS(2)
/SPPASS/NUMF
/SWITCH/ KSW1, KSW2, JF, BETA
/DATA/ C2, FOURPI, EFPL, TABLFR (15), ISW, MX1, IDEBUG
/NAMELIST/INTRPL/ IANGL, KANGL, DELNGL, DELFR, G1, G2, F1
```

Internal Subroutines Used

None

Number of Storage Locations Used

1828_{10}

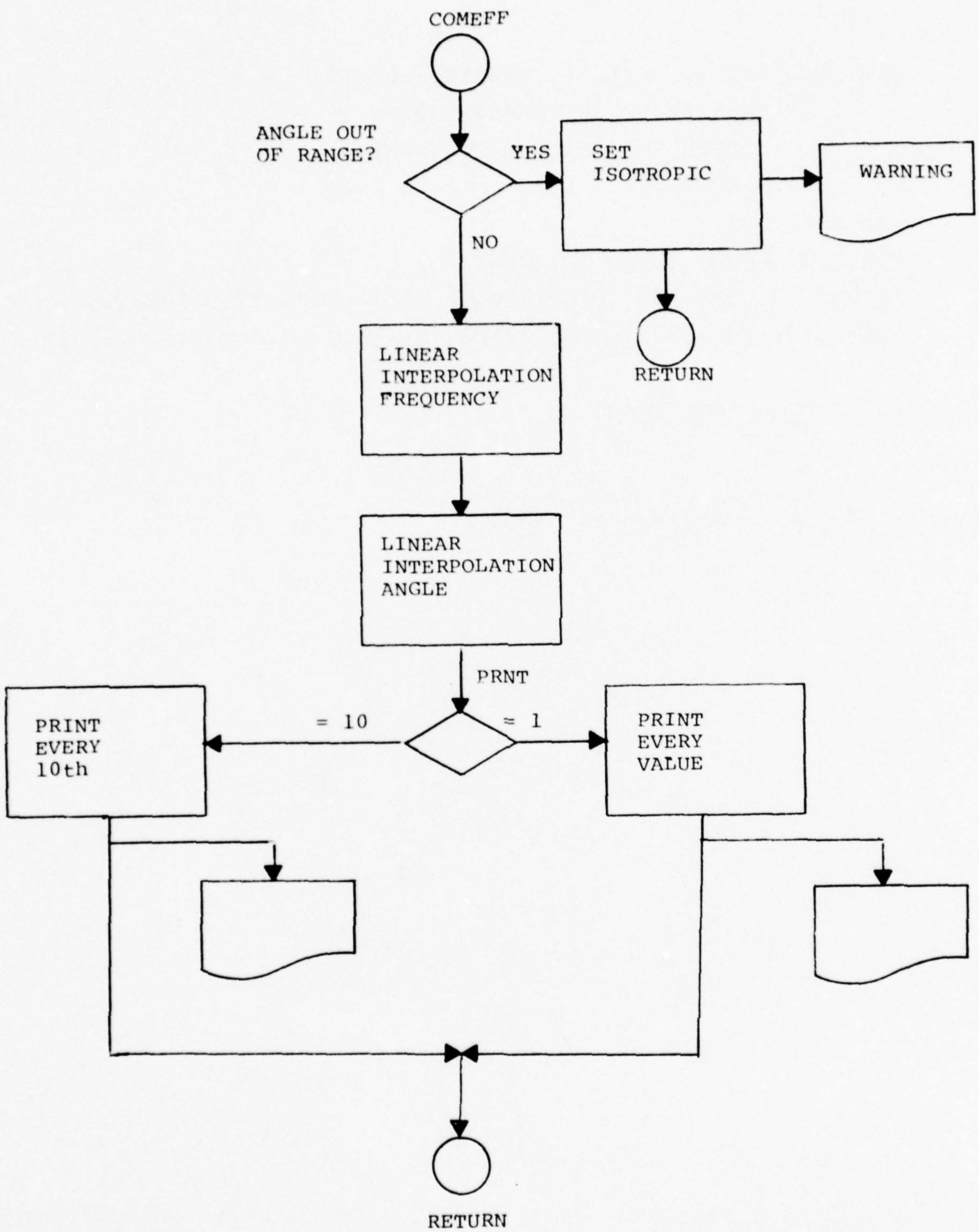


Figure 3-13. Flowchart for function F1.

3.3.4 Subroutine INITLC

Description

The subroutine INITLC initializes counters and arrays, prints the identification card and reads the antenna calibration tables when they are provided. ANTFIL is a new variable to allow reading of patterns from disk or tape files as well as card decks. Five spaces have been taken from the front of the KSW1 field for the ANTFIL parameter input. If ANTFIL is left blank or set equal to zero, and KSW1 is blank or zero, then the subroutine RDATNA will set ANTFIL equal to five and look for the input antenna patterns on the card input file. A flowchart for subroutine INITLC is presented in Figure 3-14.

Call Statement

CALL INITLC

Parameters

NONE

Common Arguments Used

```
PT (1000, 3), A(1000), PHASET (1000), TAUS(1000)
MODE (60), TIME (30), FREQ (30), SIG TAU (20,20),
SIGNO1 (20, 20)
/ANTDAT/TABL1V (181, 8), TABL1H (181,8),
        TABL2V (181, 8), TABL2H (181, 8),
        MXANGL (2), MNANGL (2), KRXN (2),
        NANGLS(2)

/CONTRO/   PLREJ

/DATA/  C2, FOURP1, EFPL, TABLFR(15), ISW, MX1, IDEBUG

/SWITCH/ KSW1, KSW2, JF, IBETA, JCARD, NEWANT
```

/SPPASS/ NOFREQ, ANTFIL, VGTOT, RGTOT, HQTOT

/NAMELIST/IINIT/NOFREQ, KSW1, KSW2,
JCARD, NEWANT,
MXANGT, MXANGR,
ANTFIL, P, BAUD,
PLRFJ, IBETA, MNANGT,
MNANGR, IDEBUG

<u>Internal Subroutines Used</u>

RDATNA

<u>Number of Storage Locations Used</u>

1880_{10}

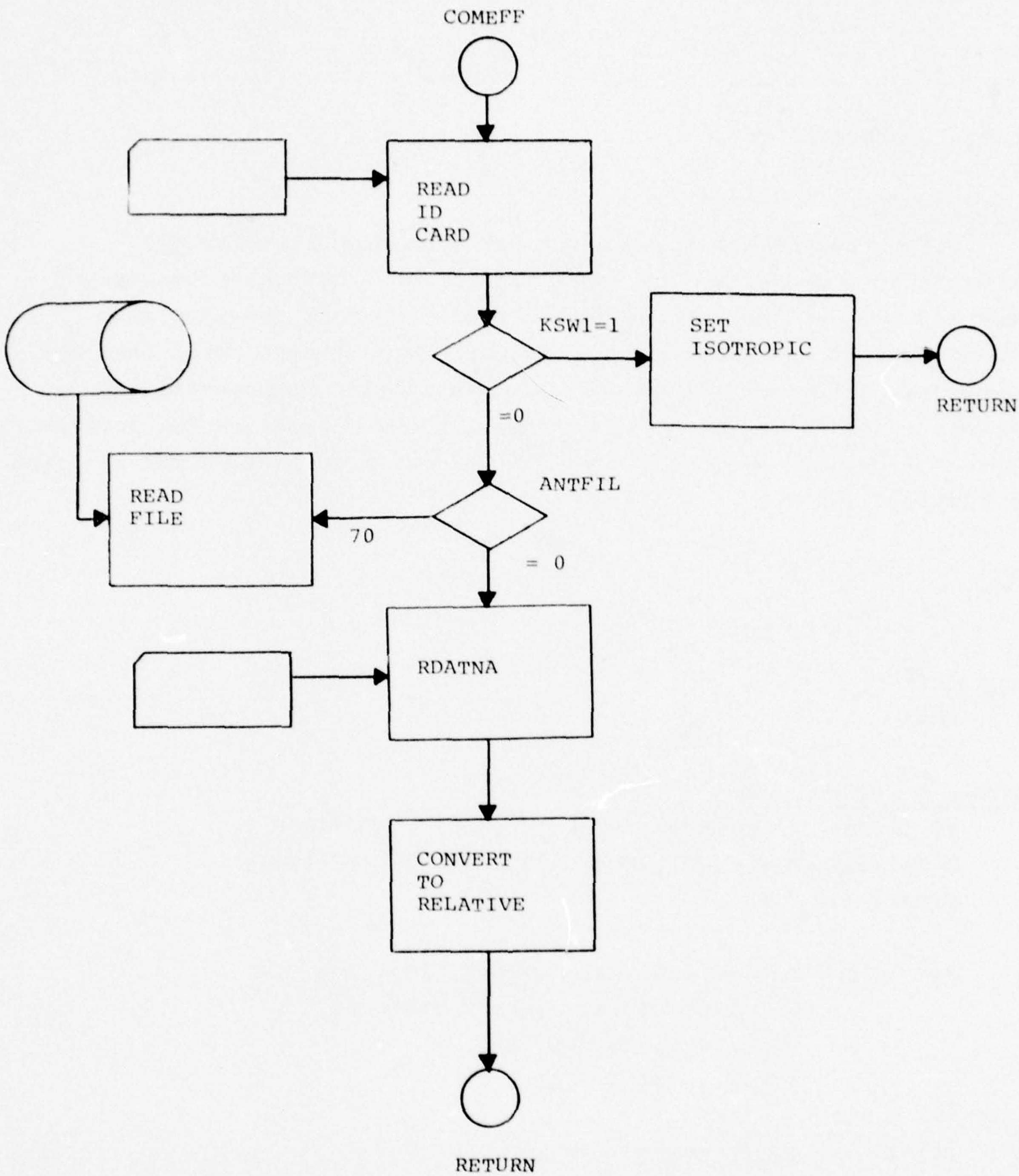


Figure 3-14. Flowchart of subroutine INITLC

3.3.5 Subroutine ONE

Description

Subroutine ONE performs the power flux summation for the ionospheric components. The modification for NUCOM/BREM consists of redefinitions of the antenna data arrays to permit the increased flexibility of the input antenna formats to be incorporated into the ionosperic components. The vertical polarization component antenna pattern takes the place of the original NUCOM II pattern for ionospheric rays. A flowchart showing the modifications to subroutine ONE is given in Figure 3-15.

Call Statement

CALL ONE

Arguments

NONE

Common Arguments Used

PT (1000. 3). A(1000). PHASET (1000). TAUS(1000).
MODE (60), TIME (30), FREQ (30), SIGTAU (20, 20),
SIGNOI (20, 20)

/ANT DAT/	TABL 1V (181, 8), TABL1H (181, 8), TABL 2V (181, 8), TABL2H (181, 8), MXANGL (2), MNANGL (2), KRXN(2), NANGLS (2)
/MIN/	DBMIN, DTMIN, DRMIN
/CONTRO/	PLREJ
/SAVSIG/	HIRAYP, IFLAG
/DATA/	C2, FOURPI, EFPL, TABLFR(15), IDUMM, MAX, IDEBUG

Internal Subroutines Used

None

Number of Storage Locations Used

3640_{10}

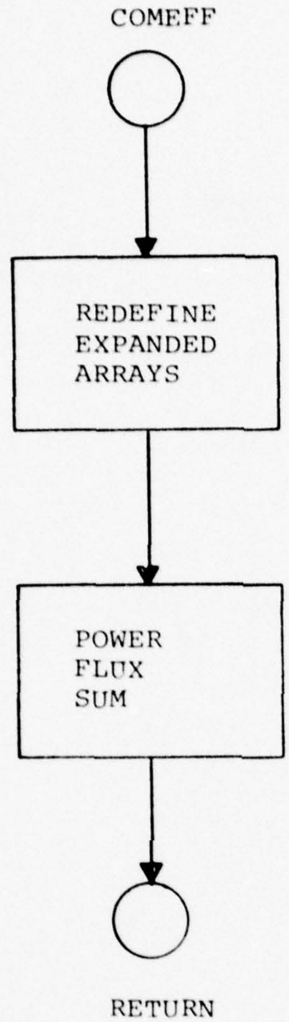


Figure 3-15. Flowchart for subroutine ONE modification.

3.3.6 Subroutine RDATNA

Description

The subroutine RDATNA reads in the antenna pattern tables if supplied. User supplied NAMELIST variables define the minimum and maximum angles for the transmitter and receiver patterns (which need not have the same values). Antenna pattern data must be supplied for every integer degree from the minimum to the maximum value. Pairs of cards are supplied for each angle, the first being the vertical component and the second the horizontal. Values are in dB relative to isotropic and blank values are assumed to be isotropic. Angles are defined relative to local horizontal as in NUCOM II except that the range of angles now extends to ±90°. The subroutine RDATNA reads the input tables for both receiver and transmitter and converts to relative power from dB. All inputs are checked for errors and appropriate warnings are printed in the event of incorrect deck setup. A flowchart of subroutine RDATNA is presented in Figure 3-16.

CALL STATEMENT

CALL RDATNA

Arguments

NONE

Common Arguments Used

```
/ANTDAT/TABL1V(181, 8), TABL1H (181, 8),
        TABL2V (181, 8), TABL2H (181, 8),
        MXANGL (2), MNANGL (2),
        KRXN(2), NANGLS (2)
/DATA/ C2, FOURPI, EFPL, TABLFR (15),
       1SW, MX1, IDEBUG
/SPPASS/ IANT, ANTFIL, VGTOT, RGTOT, HGTOT
```

Internal Subroutines Used

NONE

Number of Storage Locations Used

4740_{10}

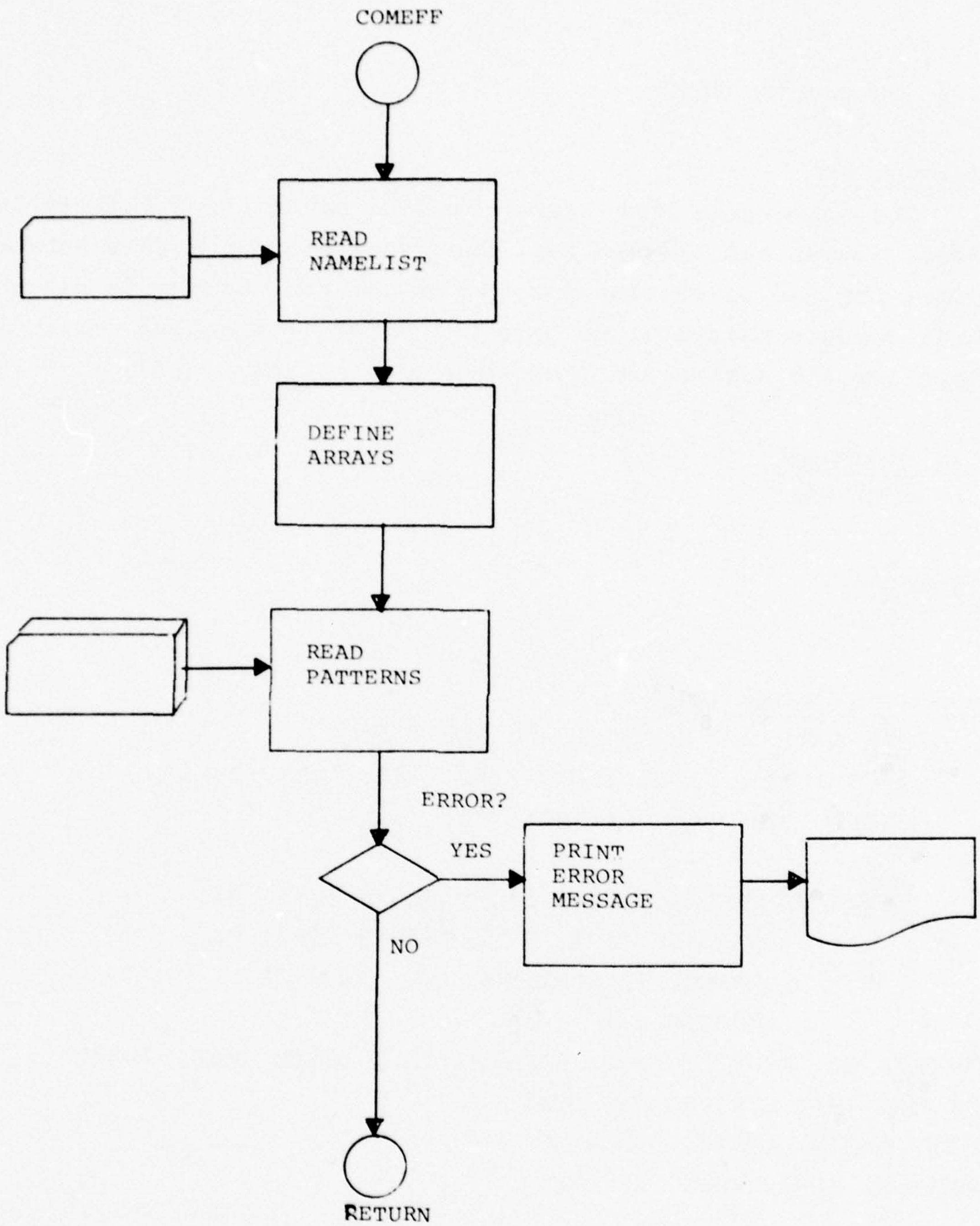


Figure 3-16. Flowchart of subroutine RDATNA.

3.3.7 Subroutine READ

Description

The subroutine READ reads the data cards and builds tables for modes, times, and frequencies. The modifications to this subroutine permit the use of aliases for the use of nonionospheric calculations. These changes maintain the original NUCOM II stacking logic. A flow-chart for the subroutine READ is given in Figure 3-17.

Call Statement

CALL READ

Arguments

NONE

Common Arguments Used

PT (1000, 3), A(1000), PHASET (1000),
TAUS (1000), MODE (60), TIME (30), FREQ (30),
SIGTAU (20, 20), SIGNOI (20, 20)

/ANTDAT/ TABL 1V (181, 8), TABL 1H (181, 8),
TABL 2V (181, 8), TABL2H (181, 8),
MXANGL (2), MNANGL (2), KRXN(2),
NANGLS (2)

/DATA/ C2, FOURPI, EFPL, TABLFR (15), IDUMM, MAX, IDEBUG
/XLIT/ AST, LIN, BLANK, STAR
/MIN/ DBMIN, DTMIN, DRMIN
/SWITCH/ KSW1, KSW2, JF, BETA

Internal Subroutines Used

ONE

Number of Storage Locations Used

2174_{10}

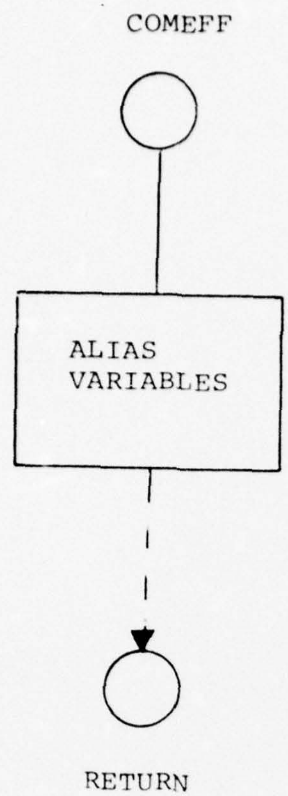


Figure 3-17. Flowchart for modification to subroutine READ.

SECTION 4.0

LIMITATIONS AND RESTRICTIONS IN NUCOM/BREM

The most important question of "just how good" a propagation prediction code is can never be fully resolved without extensive comparisons with observed data.

In most cases the accuracy of the predicted values of the nonionospheric components in NUCOM/BREM should far exceed the accuracy of the ionospheric predictions, particularly the nuclear-stressed predictions. While many of the limitations of NUCOM II are discussed in Reference 1 of Section 1, a short summary is desirable to permit comparison between uncertainties in ionospheric and nonionospheric propagation modes.

Areas of modelling uncertainty which may influence predicted values in a nuclear stressed environment include uncertainties in reaction rates and chemistry, the neglect of neutral wind drift of debris in the WEPH V phenomenology code, limited experimental data to confirm daytime and multiburst modelling, the neglect of bomb-induced field aligned E_s-like propagation modes, the neglect of deviated propagation paths due to large-scale ionospheric tilting and lateral electron density gradients, and the oversimplified modelling of shockwave effects.

For the ambient ionosphere significant areas of predictive uncertainty include the known deficiencies of the ITS world map ionospheric data, the use of a three layer parabolic isotropic ray tracing technique, the lack of modelling for ionospheric effects due to SID and auroral/geomagnetic activities, the neglect of

sporadic E and spread F modes, and the absence of modelling for deviated and chordal propagation paths. Many of these areas remain beyond the predictive abilities of any present day propagation codes.

The question of noise characterization in NUCOM II (and all other propagation codes for that matter) will also introduce uncertainties. As discussed in Section 2.5 the lack of precise knowledge of the directional and polarization properties of HF noise is perhaps as serious as all of the propagation uncertainties. The CCIR 322 data disagrees with similar measurements made by ITS(1) and recently by Raytheon Company(2) by as much as 10 dB. Furthermore, no verifiable models exist to predict the effects of nuclear disturbances on the worldwide radio noise distribution although observations of noise levels made during the Pacific Test Series suggest these effects are important.

Several areas of uncertainty exist for the nonionospheric component predictions as well. The use of the Bremmer-van der Pol equations for a smooth and homogeneous earth will limit prediction accuracy for propagation paths over highly irregular and inhomogeneous path terrain. Certain situations are to be avoided in the use of NUCOM/BREM. The seacoast transition region as discussed in Section 2. 4 should be avoided due to the recovery effects there. Our use of power flux summations for air-to-air links with ground reflections provides the envelope field and power but neglects the possible existence of deep interference nulls which may be present and modulated by aircraft motion.

Long paths over disturbed sea whose wave height spectral properties peak near the signal frequency are also to be avoided.

The modelling of the ionospheric paths from airborne terminals in NUCOM/BREM assumes the terminal to be close enough to the surface that the vertical ionospheric path geometry is not significantly changed. For realistic aircraft heights and path lengths this is not a serious limitation. By the same token the possibility of ground reflected rays then launched into the ionosphere from airborne terminals is ignored due to the obvious computational limitations in the raytracing portion of the code. Additional gain for the user supplied aircraft antenna patterns may be used to compensate for the ground reflected ionospheric components if desired.

REFERENCES

1. Amplitude and Time Statistics of Atmospheric and Man-Made Noise, R. T. Disney and A. D. Spaulding, ESSA Technical Report ERL 150-ITS 98, 1970.

2. Short-Term Stability of Noise and Interference in the 2-6 MHz Frequency Band, G. Meltz, et al, USNC-URSI Annual Meeting 1976, paper E2-1.

SECTION 5.0

SELECTED LINK EVALUATIONS

For the guidance of users of NUCOM/BREM we have included five sample link runs and one sample deck setup. The link examples have been chosen to show a variety of nonionospheric propagation modes which would be ignored by the unmodified NUCOM II code. NUCOM/BREM provides a substantial body of intermediate calculation outputs for the guidance of the user and these outputs are explained in the examples to follow.

5.1 Ground to Ground Link - Above MUF

This is an example of a short (100.02 km) HF path on a frequency sufficiently above the MUF for the path in question that no ionospheric propagation occurs.

All outputs are as from NUCOM II until RAYTRACE. The BREM input parameters are listed showing transmitter and receiver heights of zero and a Suda segmantation parameter of 10. Next appears the effective ground parameters from NWOMAP for each of the 10 Suda segments and the average value for the path. The BREM ANALYSIS RESULTS section gives the uncompensated signal powers for vertical and horizontal components and the arrived angles. The normal output from RAYTRACE indicates no ionospheric propagation for the path.

The COMEFF output shows first the NAMELIST variables input by the user, followed by the input antenna patterns, first for vertical and then for horizontal polarization. Then are given the uncompensated powers and power and antenna gain compensation factors used to obtain the compensated powers as given for vertical and horizontal components respectively. The SIGNAL ANALYSIS INCLUDING BREM ANALYSIS output gives total vertical and horizontal compensated powers at the receiver, the ionospheric signal sum, vertical and corrected noise levels, and the final corrected all mode signal to noise ratio. The last line is the normal RAYTRACE output for the situation where no ionospheric propagation occurs. The resulting all mode S/N of 10.2 dB predicts adequate copy for the 20 wpm CW transmitter of 20 kW average power modelled here.

TRANSMITTER		RECEIVER		MONTH	GMT	SSN	PATH(KM)	AZ	DELTAD	NO. CONTROL POINTS
-17.00	-128.20	-17.90	-128.20	6	12.20	20.00	100.02	180.00	100.00	2

GROUNDWAVE ONLY EXAMPLE SSP= 23.055

TIME(SEC)= -1.

HME	YME	FOE	CHI	HMF1	YMF1	FOF1	HMF2	YMF2	FOF2	ESU	ES	ESL	M(3000)	DIST
115.00	25.00	0.33	128.44	177.74	47.74	0.44	267.05	65.45	2.44	3.42	2.31	1.71	3.35	0.0
115.00	25.00	0.33	128.69	177.88	47.88	0.44	267.28	65.46	2.43	3.55	2.32	1.67	3.35	100.02

```
                         CARD INPUT
CD NO                       DATA

  1        0         0
  2   -17.00   -128.20    -17.90   -128.20       0.0       0.0
  3     4.00      1.00      4.00      0.10      1.00     75.00      0.60      1.00
  5        1
  6    12.20       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  7    -1.00       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  8        0         0         0
  0       GROUNDWAVE ONLY EXAMPLE

                                 GROUNDWAVE ONLY EXAMPLE

    90.00
```

GROUNDWAVE ONLY EXAMPLE MONTH 6 1211 GMT -1. SEC

PATH LENGTH 100.02 KM TX LAT -17.00 DEG TX LONG -128.20 DEG RX LAT -17.90 DEG RX LONG -128.20 DEG RX BEARING 180.00 DEG

								* NATURAL		*	* NUCLEAR	*	
	BETA	BETA	GROUP	PHASE	MISS		FSPCE	GRND	NONDV	DEV	NONDV	E,F1	PATH
FREQ	XMTR	RCVR	TIME	TIME	DIST	NOIS	LOSS	LOSS	ABS	ABS	ABS	ABS	LOSS
MHZ	DEG	DEG	SEC	SEC	KM	DBW	DB	DB	DB	DB	DB	DB	DB

BREM ANALYSIS INPUT

TRANS HEIGHT	RCVR HEIGHT	SIGMA	EPSILON	WIND VEL	SUDA	MILLINGTON
0.0	0.0	0.0	0.0	0.0	10	0

FROM TRANSMITTER

LATITUDE	LONGITUDE	SIGMA	EPSILON
-17.0000	128.2000	0.0010	4.0000
-17.0899	128.2000	0.0010	4.0000
-17.1799	128.2000	0.0010	4.0000
-17.2698	128.2000	0.0010	4.0000
-17.3598	128.2000	0.0010	4.0000
-17.4497	128.2000	0.0010	4.0000
-17.5397	128.2000	0.0010	4.0000
-17.6296	128.2000	0.0010	4.0000
-17.7196	128.2000	0.0010	4.0000
-17.8095	128.2000	0.0010	4.0000
-17.8994	128.2000	0.0010	4.0000
**********	**********	0.0010	4.0000

BREM ANALYSIS RESULTS

RELATIVE POWER COMPONENTS			RAY ZENITH ANGLES			
POLARIZATION		LINE OF SIGHT	TRANSMITTER		RECEIVER	
VERTICAL DBW	HORIZONTAL DBW	DBW	DIRECT DEGREES	REFLECTED DEGREES	DIRECT DEGREES	REFLECTED DEGREES
-149.	-180.		0.0		0.0	

								* NATURAL		*	* NUCLEAR	*	
FREQ	BETA XMTR	BETA RCVR	GROUP TIME	PHASE TIME	MISS DIST	NOIS	FSPCE LOSS	GRND LOSS	NONDV ABS	DEV ABS	NONDV ABS	E,F1 ABS	PATH LOSS
MHZ	DEG	DEG	SEC	SEC	KM	DBW	DB	DB	DB	DB	DB	DB	DB

NO PROPAGATION OCCURS FOR FREQUENCY AND TAKE OFF ANGLE RANGES SPECIFIED

LAST FREQ TRIED= 4.00

5.2 Ground to Air Link - Line of Sight, Below MUF

In this short link (245.0 km) both ionospheric and non-ionospheric modes exist. The transmitter is elevated at 10 km and a Suda parameter of 10 was chosen. The line of sight power figure (-92.8 dBW) is printed and the corresponding ray angles are given.

The COMEFF output indicates that we have not supplied receiver antenna pattern data for high enough angles to include the ionospheric rays; after printing the warning computation proceeds with an assumed isotropic gain for the missing values. In this case the nonionospheric power sum is close to the ionospheric mode and the net effect as shown in the all mode S/N is only a slight improvement. Were the ionospheric component to vanish, however, either through MUF failure or ionospheric stressing the nonionospheric components would of course remain.

TRANSMITTER		RECEIVER		MONTH	GMT	SSN	PATH(KM)	AZ	DELTAD	NO. CONTROL POINTS
21.00	-157.90	20.00	-160.00	6	12.00	20.00	245.20	243.42	100.00	4

NUCOM BREM AIR TO GROUND TEST SSP= 23.055

TIME(SEC)= -1.

HME	YME	FOE	CHI	HMF1	YMF1	FOF1	HMF2	YMF2	FOF2	ESU	ES	ESL	M(3000)	DIST
115.00	25.00	0.33	130.96	202.95	72.95	0.50	315.11	75.69	4.88	5.42	3.20	1.35	3.03	0.0
115.00	25.00	0.32	131.69	202.61	72.61	0.49	314.51	75.60	4.90	5.41	3.20	1.35	3.03	100.00
115.00	25.00	0.32	132.41	202.25	72.25	0.49	313.90	75.53	4.91	5.40	3.19	1.35	3.04	200.00
115.00	25.00	0.32	132.73	202.07	72.07	0.49	313.61	75.50	4.92	5.39	3.19	1.35	3.04	245.20

```
                        CARD INPUT
CD NO                       DATA

  1         0        0
  2     21.00  -157.90     20.00  -160.00      0.0       0.0
  3      3.00     1.00      3.00     0.10      1.00     75.00       0.60       0.60
  4      3.00
  5         1
  6     12.00      0.0       0.0      0.0       0.0       0.0        0.0        0.0
  7     -1.00      0.0       0.0      0.0       0.0       0.0        0.0        0.0
  8         1        1         1
  9      3.00
  0      NUCOM BREM AIR TO GROUND TEST

   21.00  157.90   20.00  160.00  6    12.00     20.00    245.20    243.42  4 31 64  1  1

  30. 32. 34. 36. 38. 40. 42. 44. 46. 48. 50. 52. 54. 56. 58. 60. 62. 64. 66. 68. 70. 72. 74. 76. 78. 80. 82. 84. 86. 88. 90. 92. 94.

  96. 98.100.105.110.115.120.125.130.135.140.150.160.170.180.190.200.220.240.260.280.300.320.340.360.380.400.450.500.600.700.  0.

  0.318E+03 0.237E+03 0.177E+03 0.133E+03 0.101E+03 0.766E+02 0.587E+02 0.452E+02 0.350E+02 0.272E+02 0.212E+02 0.165E+02 0.129E+02

  0.100E+02 0.775E+01 0.597E+01 0.458E+01 0.349E+01 0.264E+01 0.198E+01 0.147E+01 0.108E+01 0.781E+00 0.560E+00 0.396E+00 0.276E+00

  0.191E+00 0.132E+00 0.912E-01 0.631E-01 0.437E-01 0.304E-01 0.214E-01 0.153E-01 0.110E-01 0.797E-02 0.377E-02 0.193E-02 0.107E-02

  0.650E-03 0.428E-03 0.307E-03 0.233E-03 0.184E-03 0.125E-03 0.904E-04 0.678E-04 0.515E-04 0.397E-04 0.305E-04 0.187E-04 0.119E-04

  0.778E-05 0.525E-05 0.365E-05 0.256E-05 0.184E-05 0.134E-05 0.998E-06 0.754E-06 0.395E-06 0.219E-06 0.788E-07 0.332E-07 0.0

  0.119E-04 0.143E-04 0.173E-04 0.210E-04 0.254E-04 0.307E-04 0.371E-04 0.448E-04 0.542E-04 0.651E-04 0.779E-04 0.931E-04 0.111E-03

  0.131E-03 0.156E-03 0.185E-03 0.219E-03 0.258E-03 0.303E-03 0.357E-03 0.419E-03 0.492E-03 0.578E-03 0.678E-03 0.794E-03 0.930E-03

  0.111E-02 0.133E-02 0.159E-02 0.190E-02 0.227E-02 0.276E-02 0.335E-02 0.327E-02 0.256E-02 0.201E-02 0.111E-02 0.611E-03 0.348E-03

  0.196E-03 0.116E-03 0.665E-04 0.378E-04 0.212E-04 0.654E-05 0.193E-05 0.552E-06 0.155E-06 0.436E-07 0.122E-07 0.943E-09 0.727E-10

  0.557E-11 0.427E-12 0.327E-13 0.249E-14 0.189E-15 0.144E-16 0.109E-17 0.831E-19 0.132E-21 0.209E-24 0.522E-30 0.130E-35 0.0

                         NUCOM BREM AIR TO GROUND TEST
```

IONOSPHERIC PROFILE FOR PATH   NUCOM BREM AIR TO GROUND TEST   1200 GMT   -1. SEC

NU DN	HME	YME	FOE	HMF1	YMF1	FOF1	HMF2	YMF2	FOF2	RANGE
0	115.00	25.00	0.3	202.95	72.95	0.5	315.11	75.69	4.9	0.0
0	115.00	25.00	0.3	202.61	72.61	0.5	314.51	75.60	4.9	100.0
0	115.00	25.00	0.3	202.25	72.25	0.5	313.90	75.53	4.9	200.0
0	115.00	25.00	0.3	202.07	72.07	0.5	313.61	75.50	4.9	245.2

90.00

```
NUCOM BREM AIR TO GROUND TEST                                                    MONTH  6      1200 GMT       -1. SEC

PATH LENGTH   245.20 KM    TX LAT  21.00 DEG   TX LONG -157.90 DEG   RX LAT  20.00 DEG  RX LONG -160.00 DEG   RX BEARING 243.42 DEG

                                                                                * NATURAL  *    * NUCLEAR *
                                        BETA   BETA   GROUP   PHASE  MISS        FSPCE  GRND NONDV DEV   NONDV  E.F1    PATH
                                 FREQ   XMTR   RCVR   TIME    TIME   DIST  NOIS  LOSS   LOSS  ABS  ABS    ABS   ABS     LOSS

                                  MHZ    DEG    DEG    SEC     SEC    KM   DBW    DB     DB    DB   DB     DB    DB      DB

FREQ     MODE    BETA XMTR   GRND DIST   BETA RECR     PER HGT
 3.0
           4.       47.10      444.30       47.83        0.0
           4.       48.10      430.35       48.83        0.0
           4.       49.10      416.78       49.83        0.0
           4.       50.10      403.53       50.82        0.0
           4.       51.10      390.59       51.82        0.0
           4.       52.10      377.93       52.82        0.0
           4.       53.10      365.53       53.81        0.0
           4.       54.10      353.37       54.81        0.0
           4.       55.10      341.44       55.81        0.0
           4.       56.10      329.70       56.82        0.0
           4.       57.10      318.20       57.82        0.0
           4.       58.10      306.89       58.82        0.0
           4.       59.10      295.74       59.82        0.0
           4.       60.10      284.77       60.82        0.0
           4.       61.10      273.96       61.82        0.0
           4.       62.10      263.29       62.82        0.0
           4.       63.10      252.76       63.82        0.0
           4.       64.10      242.34       64.82        0.0
           4.       65.10      232.07       65.82        0.0
           4.       66.10      221.89       66.83        0.0
          44.       66.10      439.31       66.83        0.0
           4.       67.10      211.84       67.82        0.0
          44.       67.10      419.25       67.82        0.0
           4.       68.10      201.88       68.82        0.0
          44.       68.10      399.39       68.82        0.0
           4.       69.10      192.01       69.82        0.0
          44.       69.10      379.71       69.82        0.0
           4.       70.10      182.23       70.82        0.0
          44.       70.10      360.20       70.82        0.0
           4.       71.10      172.51       71.81        0.0
          44.       71.10      340.81       71.81        0.0
           4.       72.10      162.84       72.82        0.0
          44.       72.10      319.14       73.32        0.0
           4.       73.10      153.24       73.82        0.0
          44.       73.10      298.89       74.56        0.0
         444.       73.10      440.94       74.56        0.0
           4.       74.10      143.71       74.82        0.0
          44.       74.10      279.95       75.56        0.0
         444.       74.10      412.54       75.56        0.0

.F2 ............................ 3.0  63.83  64.55   1.954   1.845  -0.0 148.0 126.4   0.0  0.0  0.5    0.0   0.2    127.

MODE .F2 ..................................

 3.000 MC      63.825 DEGREES

 HEIGHT    RANGE

 140.00     67.16
```

```
  275.47    129.15
  254.46    124.40
  130.00    184.70
   90.00    203.02
    0.0     245.20
NOTE--NEXT RAY IS MORE THAN   2. KM FROM REC

.F2 ............................ 3.0  73.10  73.82   1.954   1.822 -92.0 148.0 126.4    0.0  0.0  0.6    0.0   0.2   127.
MODE .F2 ...................................
  3.000 MC       73.100 DEGREES
  HEIGHT   RANGE
  140.00     41.58
  275.63     80.12
  253.53     78.20
  130.00    116.31
   90.00    127.51
    0.0     153.24

.F2 .F2 ........................ 3.0  75.93  77.39   3.693   3.416   0.2 148.0 131.9    0.1  0.0  1.2    0.0   0.3   133.
MODE .F2 .F2 ...............................
  3.000 MC       75.934 DEGREES
  HEIGHT   RANGE
  140.00     34.30
  275.68     66.13
  254.03     64.72
  130.00     96.15
   90.00    105.31
    0.0     126.35
  140.00    158.83
  274.81    188.77
  253.32    187.44
  130.00    216.94
   90.00    225.58
    0.0     245.42
```

```
.F2 .F2 .F2 .................... 3.0  79.99  82.21   5.481   5.045  -0.9 148.0 135.3   0.1  0.0  1.9    0.0   0.5   138.
MODE .F2 .F2 .F2 ...........................
  3.000 MC      79.991 DEGREES
  HEIGHT   RANGE
  140.00     24.17
  275.74     46.62
  254.63     45.75
  130.00     67.66
   90.00     73.97
    0.0      88.47
  140.00    110.85
  275.15    131.54
  254.14    130.73
  130.00    150.81
   90.00    156.61
    0.0     169.93
  140.00    190.49
  274.57    209.43
  253.68    208.68
  130.00    226.93
   90.00    232.21
    0.0     244.35
```

BREM ANALYSIS INPUT

TRANS HEIGHT	RCVR HEIGHT	SIGMA	EPSILON	WIND VEL	SUDA	MILLINGTON
10000.000	0.0	0.0	0.0	0.0	10	0

BREM ANALYSIS RESULTS

RELATIVE POWER COMPONENTS			RAY ZENITH ANGLES			
POLARIZATION		LINE OF SIGHT	TRANSMITTER		RECEIVER	
VERTICAL	HORIZONTAL		DIRECT	REFLECTED	DIRECT	REFLECTED
DBW	DBW	DBW	DEGREES	DEGREES	DEGREES	DEGREES
		-92.8	-3.501		1.403	

CD NO		CARD INPUT DATA
1	0	1

```
ALL MODE COMEFF INPUT DATA FROM RAYTRACE


     NUCOM BREM AIR TO GROUND TEST

      -1.       4.0  3.00 63.83 64.55  1.954  1.845    127.0  148.0 1200      127.0

      -1.      44.0  3.00 75.93 77.39  3.693  3.416    133.5  148.0 1200      133.5

      -1.     444.0  3.00 79.99 82.21  5.481  5.045    137.8  148.0 1200      137.8

    G -1.       0.0  3.00  0.0   0.0    0.010000.0       0.0  148.0 1200        0.0

    &-.100000E+76-.100000E+76-92.7988         -3.501     0.0        1.403     0.0
&IINIT
NOFREQ=         1,KSW1=           0,KSW2=           0,JCARD=          0,NEWANT=           1,MXANGT=          30,MXANGR=          90,
ANTFIL=         5,P=  3.33300018    ,BAUD=  .100000016E-01,PLREJ=  2000.00000    ,IBETA=          0,MNANGT=        -30,MNANGR=
    0,IDEBUG=           0
&END
```

TRANSMITTER GAIN(DB) ANGLE(DEG) BY FREQUENCY(MHZ)
FREQUENCY

	3.0000	
-30	5.97	0.77
-29	-2.44	-3.74
-28	-8.61	-4.81
-27	-6.86	-1.46
-26	1.19	3.23
-25	8.15	4.96
-24	7.62	2.12
-23	0.08	-2.66
-22	-7.53	-5.00
-21	-8.22	-2.74
-20	-1.35	2.04
-19	6.76	4.94
-18	8.65	3.30
-17	2.59	-1.38
-16	-5.85	-4.79
-15	-8.92	-3.80
-14	-3.78	0.68
-13	4.83	4.54
-12	9.00	4.22
-11	4.90	0.02
-10	-3.71	-4.20
-9	-8.90	-4.56
-8	-5.91	-0.73
-7	2.51	3.77
-6	8.63	4.80
-5	6.81	1.42
-4	-1.27	-3.27
-3	-8.18	-4.95
-2	-7.57	-2.08
-1	0.0	2.70
0	7.57	5.00
1	8.18	2.70
2	1.27	-2.08
3	-6.81	-4.95
4	-8.63	-3.27
5	-2.51	1.42
6	5.91	4.80

7	8.90	3.77
8	3.71	-0.73
9	-4.90	-4.56
10	-9.00	-4.20
11	-4.83	0.02
12	3.78	4.22
13	8.92	4.54
14	5.85	0.68
15	-2.59	-3.80
16	-8.65	-4.79
17	-6.76	-1.38
18	1.35	3.30
19	8.22	4.94
20	7.53	2.04
21	-0.08	-2.74
22	-7.62	-5.00
23	-8.15	-2.66
24	-1.19	2.12
25	6.86	4.96
26	8.61	3.23
27	2.44	-1.46
28	-5.97	-4.81
29	-8.89	-3.74
30	3.64	0.77

RECEIVER GAIN(DB) ANGLE(DEG) BY FREQUENCY(MHZ)
FREQUENCY

	3.0000	
0	7.57	5.00
1	8.18	2.70
2	1.27	-2.08
3	-6.81	-4.95
4	-8.63	-3.27
5	-2.51	1.42
6	5.91	4.80
7	8.90	3.77
8	3.71	-0.73
9	-4.90	-4.56
10	-9.00	-4.20
11	-4.83	0.02
12	3.78	4.22
13	8.92	4.54
14	5.85	0.68
15	-2.59	-3.80
16	-8.65	-4.79
17	-6.76	-1.38
18	1.35	3.30
19	8.22	4.94
20	7.53	2.04
21	-0.08	-2.74
22	-7.62	-5.00
23	-8.15	-2.66
24	-1.19	2.12
25	6.86	4.96
26	8.61	3.23
27	2.44	-1.46
28	-5.97	-4.81
29	-8.89	-3.74
30	3.64	0.77
31	4.96	4.57
32	9.00	4.17
33	4.76	-0.07
34	-3.85	-4.24
35	-8.93	-4.52

36	-5.79	-0.64
37	2.67	3.83
38	8.67	4.78
39	6.71	1.33
40	-1.43	-3.33
41	-8.25	-4.94
42	-7.49	-2.00
43	0.16	2.78
44	7.66	5.00
45	8.12	2.63
46	1.11	-2.16
47	-6.91	-4.96
48	-8.58	-3.20
49	-2.36	1.50
50	6.03	4.82
51	8.88	3.71
52	3.56	-0.81
53	-5.03	-4.59
54	-9.00	-4.15
55	-4.69	0.11
56	3.93	4.27
57	8.94	4.50
58	5.73	0.60
59	-2.74	-3.86
60	-8.70	-4.76
61	-6.65	-1.29
62	1.51	3.37
63	8.28	4.93
64	7.44	1.96
65	-0.24	-2.81
66	-7.70	-5.00
67	-8.08	-2.59
68	-1.03	2.20
69	6.97	4.97
70	8.56	3.17
71	2.28	-1.55
72	-6.09	-4.84
73	-8.87	-3.68
74	-3.49	0.86
75	5.09	4.61
76	9.00	4.12
77	4.63	-0.15
78	-4.00	-4.29
79	-8.94	-4.48
80	-5.67	0.55
81	2.82	3.88
82	8.72	4.75
83	6.60	1.25
84	-1.58	-3.40
85	-8.31	-4.92
86	-7.40	-1.92
87	0.32	2.85
88	7.74	5.00
89	8.05	2.55
90	0.95	-2.24

```
NUCOM BREM AIR TO GROUND TEST

*****     ANGLE  63.83000  OUT OF SPECIFIED RANGE:   30  --    -30
     *****     ANTENNA CALIBRATION TABLES NOT USED  *

*****     ANGLE  63.83000  OUT OF SPECIFIED RANGE:   30  --    -30
     *****     ANTENNA CALIBRATION TABLES NOT USED  *

*****     ANGLE  75.92999  OUT OF SPECIFIED RANGE:   30  --    -30
     *****     ANTENNA CALIBRATION TABLES NOT USED  *

*****     ANGLE  75.92999  OUT OF SPECIFIED RANGE:   30  --    -30
     *****     ANTENNA CALIBRATION TABLES NOT USED  *

*****     ANGLE  79.99001  OUT OF SPECIFIED RANGE:   30  --    -30
     *****     ANTENNA CALIBRATION TABLES NOT USED  *

*****     ANGLE  79.99001  OUT OF SPECIFIED RANGE:   30  --    -30
     *****     ANTENNA CALIBRATION TABLES NOT USED  *
```

FSV	DBV	DBH	DBL	TBD	TBR	RBD	RBR
8	-.100000E+76	-.100000E+76	-92.7988	-3.50100	.0	1.40300	.0

DB FROM BREM	P	TRANSMITTER GN	RECEIVER GAIN	COMPENSATED POWER
-92.7987976	5.2283525	-3.4693565	6.4992867	-84.5404816
-92.7987976	5.2283525	-4.0276051	1.3395395	-90.2584839

****

SIGNAL ANALYSIS INCLUDING BREM ANALYSIS

GROUND OR REFLECTED VERTICAL DBW	GROUND OR REFLECTED HORIZONTAL DBW	DIRECT VERTICAL DBW	DIRECT HORIZONTAL DBW	IONOSPHERIC SIGNAL SUM DBW	VERTICAL NOISE -DBW	CORRECTED NOISE -DBW	CORRECTED ALL MODE S/N RATIO
-.100000E+76	-.100000E+76	-84.5405	-90.2585	-86.7250	148.000	146.085	64.2695

****

GMT	TIME (SEC)	FREQ	NMODES	MGT (MS)	2*SIGMA (MS)	SIGNAL (-DBW)	S/N (DB)	EFPL (DB)	(S/N)MAX (DB)
1200	43200.	3.0	3	2.6405	2.5426	0.867E+02	0.613E+02	0.126E+03	0.197E+03

5.3 Air to Air Link - Line of Sight, Above MUF

This example shows a 600.08 km air to air link between elevated terminals at 10 km operating above the MUF. The output from RAYTRACE shows both direct line of sight and ground reflected signal components as well as the effective ground parameters at the reflection point as determined by NWOMAP and FSGEPS. The all mode S/N shown in the COMEFF section shows the nonionospheric mode ignored by the unmodified NUCOM II. The predicted value of 48.15 dB is excellent for the 3 kHz SSB link modelled.

TRANSMITTER		RECEIVER		MONTH	GMT	SSN	PATH(KM)	AZ	DELTAD	NO. CONTROL POINTS
-17.00	-128.20	-22.40	-128.20	6	12.10	20.00	600.08	180.00	100.00	7

AIR TO AIR LINE OF SIGHT EXAMPLE　　　SSP= 23.055

TIME(SEC)= -1.

HME	YME	FOE	CHI	HMF1	YMF1	FOF1	HMF2	YMF2	FOF2	ESU	ES	ESL	M(3000)	DIST
115.00	25.00	0.32	129.82	177.92	47.92	0.42	267.38	65.49	2.50	3.43	2.32	1.72	3.35	0.0
115.00	25.00	0.32	130.06	178.08	48.08	0.42	267.62	65.50	2.49	3.56	2.33	1.68	3.35	100.00
115.00	25.00	0.31	130.30	178.33	48.33	0.42	268.04	65.55	2.48	3.67	2.30	1.63	3.34	200.00
115.00	25.00	0.31	130.52	178.69	48.69	0.41	268.66	65.63	2.48	3.76	2.25	1.58	3.34	300.00
115.00	25.00	0.31	130.73	179.15	49.15	0.41	269.46	65.74	2.48	3.82	2.17	1.52	3.33	400.00
115.00	25.00	0.31	130.93	179.70	49.70	0.41	270.42	65.88	2.48	3.85	2.07	1.47	3.33	500.00
115.00	25.00	0.30	131.12	180.34	50.34	0.41	271.54	66.04	2.49	3.86	1.96	1.42	3.32	600.08

CARD INPUT DATA

CD NO								
1	0	0						
2	-17.00	-128.20	-22.40	-128.20	0.0	0.0		
3	4.00	1.00	4.00	0.10	1.00	75.00	0.60	1.00
5	1							
6	12.10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	-1.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0	0	0					
0	AIR TO AIR LINE OF SIGHT EXAMPLE							

AIR TO AIR LINE OF SIGHT EXAMPLE

90.00

BREM ANALYSIS INPUT

TRANS HEIGHT	RCVR HEIGHT	SIGMA	EPSILON	WIND VEL	SUDA	MILLINGTON
10000.000	10000.000	0.0	0.0	0.0	10	0

REFLECTED RAY CALCULATIONS:
AT LAT -19.279 AND LONG 128.200 SIGMA = 0.001 EPSILON = 4.000 (EFFECTIVE VALUES)

BREM ANALYSIS RESULTS

RELATIVE POWER COMPONENTS			RAY ZENITH ANGLES			
POLARIZATION		LINE OF SIGHT	TRANSMITTER		RECEIVER	
VERTICAL DBW	HORIZONTAL DBW	DBW	DIRECT DEGREES	REFLECTED DEGREES	DIRECT DEGREES	REFLECTED DEGREES
-108.	-107.	-103.	-2.708	-3.397	-2.708	-3.397

```
ALL MODE COMEFF INPUT DATA FROM RAYTRACE


          AIR TO AIR LINE OF SIGHT EXAMPLE

       G   -1.     0.0     4.00  0.0   0.0     0.010000.0  10000.0  148.6 1206       0.0

       8-107.992     -107.297     -103.068         -2.708     -3.397     -2.708     -3.397
&IINIT
NOFREQ=          1,KSW1=          0,KSW2=          1,JCARD=          0,NEWANT=          1,MXANGT=          0,MXANGR=          0,
ANTFIL=          5,P= 3.33300018     ,BAUD=  .100000016E-01,PLREJ=  400.000000     ,IBETA=          0,MNANGT=          -5,MNANGR=
      -5,IDEBUG=          0
&END

    TRANSMITTER GAIN(DB)   ANGLE(DEG) BY FREQUENCY(MHZ)
                           FREQUENCY


               4.0000
    -5     -3.50  -2.40
    -4     -3.40  -2.30
    -3     -3.30  -2.20
    -2     -3.20  -2.10
    -1     -3.10  -2.00
     0     -3.00  -1.90

    RECEIVER GAIN(DB)   ANGLE(DEG) BY FREQUENCY(MHZ)
                           FREQUENCY


               4.0000
    -5     -3.50  -2.40
    -4     -3.40  -2.30
    -3     -3.30  -2.20
    -2     -3.20  -2.10
    -1     -3.10  -2.00
     0     -3.00  -1.90
```

KSW	DBV	DBH	DBL	TBD	TBR	RBD	RBR
&	-107.992	-107.297	-103.068	-2.70800	-3.39700	-2.70800	-3.39700

DB FROM BREM	P	TRANSMITTER GN	RECEIVER GAIN	COMPENSATED POWER
-103.067993	5.2283525	-3.2705603	-3.2705603	-104.380737
-103.067993	5.2283525	-2.1705599	-2.1705599	-102.180725
-107.992004	5.2283525	-3.3394241	-3.3394241	-109.442474
-107.296997	5.2283525	-2.2394238	-2.2394238	-106.547455

****

SIGNAL ANALYSIS INCLUDING BREM ANALYSIS

GROUND OR REFLECTED		DIRECT					
VERTICAL DBW	HORIZONTAL DBW	VERTICAL DBW	HORIZONTAL DBW	IONOSPHERIC SIGNAL SUM DBW	VERTICAL NOISE -DBW	CORRECTED NOISE -DBW	CORRECTED ALL MODE S/N RATIO
-109.442	-106.547	-104.381	-102.181	-.100000E+76	148.600	145.916	47.0728

****

GMT	TIME (SEC)	FREQ	NMODES	MGT (MS)	2*SIGMA (MS)	SIGNAL (-DBW)	S/N (DB)	EFPL (DB)	(S/N)MAX (DB)
1206	-1.	1.0	0	0.0	0.0	0.0	0.0	0.0	0.378E+02

5.4 Air to Air Link - Beyond Line of Sight, Above MUF

This 800.1 km link operates above the MUF between terminals at a height of 10 km and no ionospheric propagation occurs. A Suda factor of 10 has been chosen and the returned constants as shown indicate that a sea path is involved. The resulting all mode S/N of 17.7 dB is that of the groundwave mode only and indicates that the link in question which has been modelled as a 3 kHz SSB circuit with a 1 kW transmitter will maintain acceptable communications in the absence of skywave propagation.

TRANSMITTER		RECEIVER		MONTH	GMT	SSN	PATH(KM)	AZ	DELTAD	NO. CONTROL POINTS
-17.00	-128.20	-24.20	-128.20	6	12.10	20.00	800.10	180.00	100.00	9

AIR TO AIR BEYOND LOS EXAMPLE   SSP= 23.055

TIME(SEC)= -1.

HME	YME	FOE	CHI	HMF1	YMF1	FOF1	HMF2	YMF2	FOF2	ESU	ES	ESL	M(3000)	DIST
115.00	25.00	0.32	129.82	177.92	47.92	0.42	267.38	65.49	2.50	3.43	2.32	1.72	3.35	0.0
115.00	25.00	0.32	130.06	178.08	48.08	0.42	267.62	65.50	2.49	3.56	2.33	1.68	3.35	100.00
115.00	25.00	0.31	130.30	178.33	48.33	0.42	268.04	65.55	2.48	3.67	2.30	1.63	3.34	200.00
115.00	25.00	0.31	130.52	178.69	48.69	0.41	268.66	65.63	2.48	3.76	2.25	1.58	3.34	300.00
115.00	25.00	0.31	130.73	179.15	49.15	0.41	269.46	65.74	2.48	3.82	2.17	1.52	3.33	400.00
115.00	25.00	0.31	130.93	179.70	49.70	0.41	270.42	65.88	2.48	3.85	2.07	1.47	3.33	500.00
115.00	25.00	0.30	131.12	180.34	50.34	0.41	271.54	66.04	2.49	3.86	1.96	1.42	3.32	600.00
115.00	25.00	0.30	131.30	181.05	51.05	0.40	272.79	66.21	2.50	3.83	1.83	1.37	3.31	700.00
115.00	25.00	0.30	131.46	181.83	51.83	0.40	274.15	66.40	2.52	3.78	1.70	1.32	3.30	800.10

```
                              CARD INPUT
CD NO                            DATA

  1          0         0
  2     -17.00   -128.20    -24.20   -128.20       0.0       0.0
  3       4.00      1.00      4.00      0.10      1.00     75.00      0.60      1.00
  5          1
  6      12.10       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  7      -1.00       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  8          0         0         0
  0        AIR TO AIR BEYOND LOS EXAMPLE

                                      AIR TO AIR BEYOND LOS EXAMPLE

    90.00
```

BREM ANALYSIS INPUT

TRANS HEIGHT	RCVR HEIGHT	SIGMA	EPSILON	WIND VEL	SUDA	MILLINGTON
10000.000	10000.000	0.0	0.0	0.0	10	0

FROM TRANSMITTER

LATITUDE	LONGITUDE	SIGMA	EPSILON
-17.0000	128.2000	0.0010	4.0000
-17.7195	128.2000	0.0010	4.0000
-18.4390	128.2000	0.0010	4.0000
-19.1586	128.2000	0.0010	4.0000
-19.8781	128.2000	0.0010	4.0000
-20.5976	128.2000	0.0010	4.0000
-21.3171	128.2000	0.0010	4.0000
-22.0367	128.2000	0.0010	4.0000
-22.7562	128.2000	0.0010	4.0000
-23.4757	128.2000	0.0010	4.0000
-24.1952	128.2000	0.0010	4.0000
**********	**********	0.0010	4.0000

BREM ANALYSIS RESULTS

RELATIVE POWER COMPONENTS			RAY ZENITH ANGLES			
POLARIZATION		LINE OF SIGHT	TRANSMITTER		RECEIVER	
VERTICAL DBW	HORIZONTAL DBW	DBW	DIRECT DEGREES	REFLECTED DEGREES	DIRECT DEGREES	REFLECTED DEGREES
-133.	-133.		0.0		0.0	

```
ALL MODE COMEFF INPUT DATA FROM RAYTRACE


        AIR TO AIR BEYOND LOS EXAMPLE

     G   -1.     0.0    4.00  0.0   0.0     0.010000.0  10000.0  148.6 1206       0.0

     &-132.512     -132.891     -.100000E+76     0.0        0.0        0.0        0.0
$IINIT
$OFREQ=          1,KSW1=             0,KSW2=             1,JCARD=            0,NEWANT=            1,MXANGT=            0,MXANGR=            0,
$NTFIL=          5,P=  3.33300018    ,BAUD=  .100000016E-01,PLREJ=  400.000000    ,IBETA=            0,MNANGT=           -5,MNANGR=
    -5,IDEBUG=            0
$END

   TRANSMITTER GAIN(DB)    ANGLE(DEG) BY FREQUENCY(MHZ)
                         FREQUENCY


              4.0000
   -5     -3.50   -2.40
   -4     -3.40   -2.30
   -3     -3.30   -2.20
   -2     -3.20   -2.10
   -1     -3.10   -2.00
    0     -3.00   -1.90

   RECEIVER GAIN(DB)   ANGLE(DEG) BY FREQUENCY(MHZ)
                         FREQUENCY


              4.0000
   -5     -3.50   -2.40
   -4     -3.40   -2.30
   -3     -3.30   -2.20
   -2     -3.20   -2.10
   -1     -3.10   -2.00
    0     -3.00   -1.90
```

KSW	DBV	DBH	DBL	TBD	TBR	RBD	RBR
8	-132.512	-132.891	-.100000E+76	.0	.0	.0	.0

DB FROM BREM	P	TRANSMITTER GN	RECEIVER GAIN	COMPENSATED POWER
-132.511993	5.2283525	-2.9999981	-2.9999981	-133.283600
-132.891006	5.2283525	-1.8999987	-1.8999987	-131.462631

****

SIGNAL ANALYSIS INCLUDING BREM ANALYSIS

GROUND OR REFLECTED		DIRECT					
VERTICAL DBW	HORIZONTAL DBW	VERTICAL DBW	HORIZONTAL DBW	IONOSPHERIC SIGNAL SUM DBW	VERTICAL NOISE -DBW	CORRECTED NOISE -DBW	CORRECTED ALL MODE S/N RATIO
-133.284	-131.463	-.100000E+76	-.100000E+76	-.100000E+76	148.600	145.916	16.6483

****

GMT	TIME (SEC)	FREQ	NMODES	MGT (MS)	2*SIGMA (MS)	SIGNAL (-DBW)	S/N (DB)	EFPL (DB)	(S/N)MAX (DB)
1206	-1.	1.0	0	0.0	0.0	0.0	0.0	0.0	0.378E+02

5.5 Air to Air Link - Beyond Line of Sight, Nuclear Stressed Ionosphere

The same 800.1 km link between 10 km elevated terminals is computed for a nuclear stressed ionosphere produced by detonation of a 1.3 Mt device at a height of 70 km midway along the path.

The output from ORDER indicates a nuclear stressed daytime ionosphere and the RAYTRACE output for the ionospheric components shows extremely high nonderivative absorption. The corrected all mode S/N now reflects just beyond the horizon groundwave component since the ionospheric rays have been blacked out. Again, the indicated S/N of 15.3 dB is adequate for communications on this circuit.

TRANSMITTER		RECEIVER		MONTH	GMT	SSN	PATH(KM)	AZ	DELTAD	NO. CONTROL POINTS
-17.00	-128.20	-24.20	-128.20	6	2.20	20.00	800.10	180.00	100.00	9

STRESSED TEST RUN AIR TO AIR SSP= 23.055

HME	YME	FOE	CHI	HMF1	YMF1	FOF1	HMF2	YMF2	FOF2	ESU	ES	ESL	M(3000)	DIST
115.00	25.00	1.52	91.99	169.05	39.05	1.91	273.18	84.60	7.74	5.86	3.40	2.36	3.29	0.0
115.00	25.00	1.51	92.35	167.52	37.52	1.87	269.82	83.54	7.55	5.68	3.30	2.32	3.32	100.00
115.00	25.00	1.49	92.71	166.10	36.10	1.84	266.70	82.55	7.34	5.52	3.20	2.28	3.34	200.00
115.00	25.00	1.48	93.07	164.80	34.80	1.81	263.82	81.63	7.11	5.37	3.08	2.22	3.36	300.00
115.00	25.00	1.46	93.42	163.62	33.62	1.78	261.19	80.76	6.88	5.23	2.97	2.16	3.38	400.00
115.00	25.00	1.45	93.78	162.57	32.57	1.75	258.80	79.95	6.64	5.12	2.85	2.10	3.40	500.00
115.00	25.00	1.44	94.14	161.64	31.64	1.72	256.66	79.19	6.41	5.01	2.74	2.04	3.42	600.00
115.00	25.00	1.42	94.49	160.84	30.84	1.70	254.74	78.49	6.17	4.93	2.63	1.98	3.43	700.00
115.00	25.00	1.41	94.85	160.15	30.15	1.67	253.05	77.83	5.95	4.85	2.53	1.92	3.44	800.10

DATA IS IN BEGIN COMPUTATION

TIME	HDB1	HDB2	HDB3	HDB5	RDB1	RDB2	RDB3	RDB5	DFB1	DFB2	DFB3	DFB5
60.	144.	0.	0.	0.	14.	0.	0.	0.	0.	0.	0.	0.

TRANSMITTER RECEIVER PATH AZIMUTH AND LENGTH
-17.000 -128.200 -24.200 -128.200 180.000 800.10254

EVALUATION TIME (SEC) = 60.000

BURST TIME 0.0 LATITUDE -20.00 LONGITUDE -128.00 YIELD 1.30 ALTITUDE 70.00

DISTANCE OF FIELD POINT FROM BURST L = 334.04 DISTANCE FROM TRANSMITTER = 0.0

HT	AMBIENT	NUCLEAR	HT	AMBIENT	NUCLEAR	HT	AMBIENT	NUCLEAR	HT	AMBIENT	NUCLEAR	HT	AMBIENT	NUCLEAR
30.	0.40E-02	0.88E+01	70.	0.14E+03	0.86E+05	115.	0.29E+05	0.98E+05	215.	0.39E+06	0.40E+06	400.	0.30E+06	0.30E+06
35.	0.16E-01	0.39E+02	72.	0.16E+03	0.82E+05	125.	0.24E+05	0.99E+05	225.	0.50E+06	0.51E+06	425.	0.23E+06	0.23E+06
40.	0.54E-01	0.11E+03	75.	0.21E+03	0.74E+05	135.	0.21E+05	0.79E+05	240.	0.63E+06	0.63E+06	450.	0.18E+06	0.18E+06
45.	0.16E+00	0.24E+03	80.	0.40E+03	0.61E+05	145.	0.28E+05	0.67E+05	255.	0.71E+06	0.71E+06	500.	0.10E+06	0.10E+06
50.	0.42E+00	0.52E+03	85.	0.88E+03	0.58E+05	155.	0.39E+05	0.71E+05	270.	0.74E+06	0.74E+06	600.	0.35E+05	0.35E+05
55.	0.32E+01	0.24E+04	90.	0.19E+04	0.56E+05	165.	0.44E+05	0.69E+05	285.	0.73E+06	0.73E+06	700.	0.12E+05	0.12E+05
60.	0.22E+02	0.17E+05	92.	0.44E+04	0.59E+05	175.	0.44E+05	0.63E+05	300.	0.69E+06	0.69E+06			
62.	0.44E+02	0.34E+05	96.	0.12E+05	0.64E+05	185.	0.37E+05	0.53E+05	325.	0.59E+06	0.59E+06			
65.	0.97E+02	0.70E+05	100.	0.18E+05	0.70E+05	195.	0.13E+06	0.15E+06	350.	0.48E+06	0.48E+06			
68.	0.13E+03	0.86E+05	105.	0.24E+05	0.79E+05	205.	0.27E+06	0.28E+06	375.	0.38E+06	0.38E+06			

DISTANCE OF FIELD POINT FROM BURST L = 167.93 DISTANCE FROM TRANSMITTER = 500.00

HT	AMBIENT	NUCLEAR	HT	AMBIENT	NUCLEAR	HT	AMBIENT	NUCLEAR	HT	AMBIENT	NUCLEAR	HT	AMBIENT	NUCLEAR
30.	0.40E-02	0.51E+02	70.	0.14E+03	0.12E+06	115.	0.26E+05	0.12E+06	215.	0.38E+06	0.42E+06	400.	0.17E+06	0.17E+06
35.	0.15E-01	0.16E+03	72.	0.15E+03	0.11E+06	125.	0.22E+05	0.19E+06	225.	0.45E+06	0.48E+06	425.	0.13E+06	0.13E+06
40.	0.54E-01	0.33E+03	75.	0.19E+03	0.98E+05	135.	0.20E+05	0.24E+06	240.	0.51E+06	0.54E+06	450.	0.98E+05	0.98E+05
45.	0.16E+00	0.68E+03	80.	0.37E+03	0.73E+05	145.	0.27E+05	0.24E+06	255.	0.54E+06	0.54E+06	500.	0.55E+05	0.55E+05
50.	0.42E+00	0.14E+04	85.	0.79E+03	0.63E+05	155.	0.36E+05	0.25E+06	270.	0.54E+06	0.54E+06	600.	0.18E+05	0.18E+05
55.	0.32E+01	0.47E+04	90.	0.17E+04	0.59E+05	165.	0.38E+05	0.20E+06	285.	0.51E+06	0.51E+06	700.	0.55E+04	0.55E+04
60.	0.22E+02	0.25E+05	92.	0.40E+04	0.61E+05	175.	0.32E+05	0.16E+06	300.	0.46E+06	0.46E+06			
62.	0.44E+02	0.47E+05	96.	0.11E+05	0.66E+05	185.	0.10E+06	0.20E+06	325.	0.38E+06	0.38E+06			
65.	0.96E+02	0.97E+05	100.	0.17E+05	0.72E+05	195.	0.20E+06	0.27E+06	350.	0.30E+06	0.30E+06			
68.	0.13E+03	0.12E+06	105.	0.22E+05	0.84E+05	205.	0.30E+06	0.35E+06	375.	0.23E+06	0.23E+06			

INPUT TAPE ,RAYTRACE, COMPLETED FOR THIS TIME

TRANSMITTER		RECEIVER		PATH AZIMUTH AND LENGTH	
-17.000	-128.200	-24.200	-128.200	180.000	800.10254

LAT(DEGS)	LONG(DEGS)	DISTANCE FROM TRANSMITTER OF POINTS ON PATH
-17.000	-128.200	0.0
-17.900	-128.200	100.00000
-18.800	-128.200	200.00000
-19.700	-128.200	300.00000
-20.600	-128.200	400.00000
-21.499	-128.200	500.00000
-22.399	-128.200	600.00000
-23.299	-128.200	700.00000
-24.200	-128.200	800.10254

```
INPUT DATA CARDS
1       15        2         0         0         5         .5        1.
```

TRANSMITTER		RECEIVER		MON	GMT	SSN	DR	BETA	DELTAD	NAC
[illegible]	-128.20	-24.20	-128.20	6	0.22E+01	0.20E+02	0.80E+03	0.18E+03	0.10E+03	9

STRESSED TEST RUN AIR TO AIR TIME= 60.0

INDICATOR 0=NITE-AMB 2=NITE-NUC X=F-REGION CALCULATIONS AND,
1=DAY -AMB 3=DAY -NUC + OR - 7 DEG OF EQUATOR

INDICATOR	DISTANCE	HME	YMF	FOE	HMF1	YMF1	FOF1	HMF2	YMF2	FOF2		ENEC DEN(65KM)
3	0.	121.	43.5	2.8	171.	25.2	2.4	274.	87.9	7.7		0.70E+05
3	100.	115.	32.3	2.9	178.	46.5	3.9	271.	92.3	7.5		0.81E+05
3	200.	115.	31.7	3.0	186.	55.5	6.1	266.	45.8	8.7		0.11E+06
3	300.	115.	34.8	3.0	188.	55.2	7.9	264.	41.1	9.0		0.19E+06
3	400.	115.	32.9	3.0	186.	54.9	7.3	264.	43.1	8.4		0.16E+06
3	500.	115.	31.7	2.9	147.	15.9	5.7	256.	108.9	6.6		0.97E+05
3	600.	129.	47.1	3.2	176.	23.6	1.4	259.	82.9	6.4	E3	0.77E+05
3	700.	118.	44.3	2.6	165.	20.3	2.0	255.	90.4	6.2		0.68E+05
3	800.	109.	49.4	2.2	166.	23.2	1.8	254.	87.9	5.9		0.60E+05

CARD INPUT
DATA

CD NO								
1	0	0						
2	-17.00	-128.20	-24.20	-128.20	0.0	0.0		
3	4.00	1.00	4.00	0.10	1.00	75.00	0.60	0.60
5	1							
6	2.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	60.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	0	0	0					
0	STRESSED TEST RUN AIR TO AIR							

STRESSED TEST RUN AIR TO AIR

60.00

STRESSED TEST RUN AIR TO AIR MONTH 6 211 GMT 60. SEC

PATH LENGTH 800.10 KM TX LAT -17.00 DEG TX LONG -128.20 DEG RX LAT -24.20 DEG RX LONG -128.20 DEG RX BEARING 180.00 DEG

	FREQ	BETA XMTR	BETA RCVR	GROUP TIME	PHASE TIME	MISS DIST	NOIS	FSPCE LOSS	* NATURAL GRND LOSS	NONDV ABS	DEV ABS *	* NUCLEAR NONDV ABS	E.F1 ABS *	PATH LOSS
	MHZ	DEG	DEG	SEC	SEC	KM	DBW	DB	DB	DB	DB	DB	DB	DB
.E	4.0	11.75	8.74	2.744	2.740	-1.1	151.	PATH LENGTH EXCEEDS 9000.						
NOTE--NEXT RAY IS MORE THAN 10. KM FROM REC														
.E	4.0	13.10	10.30	2.744	2.739	-81.4	151.	PATH LENGTH EXCEEDS 9000.						
.E .E	4.0	21.00	29.64	2.991	2.917	4.7	151.	PATH LENGTH EXCEEDS 9000.						
NOTE--NEXT RAY IS MORE THAN 10. KM FROM REC														
.E .E	4.0	28.10	32.21	3.004	2.910	-96.3	151.5	130.1	0.1	0.0	0.0	7732.9	22.0	7885.
NOTE--NEXT RAY IS MORE THAN 10. KM FROM REC														
.E .F2	4.0	45.10	57.91	4.076	2.871	-36.2	151.5	132.7	0.1	0.0	0.5	5361.4	61.2	5556.
NOTE--NEXT RAY IS MORE THAN 10. KM FROM REC														
.F1 .F1 $E .F2	4.0	46.10	42.32	4.155	2.882	81.1	151.5	132.9	0.1	0.0	0.2	5574.4	65.2	5773.

BREM ANALYSIS INPUT

TRANS HEIGHT	RCVR HEIGHT	SIGMA	EPSILON	WIND VEL	SUDA	MILLINGTON
10000.000	10000.000	0.0	0.0	0.0	10	0

FROM TRANSMITTER

LATITUDE	LONGITUDE	SIGMA	EPSILON
-17.0000	128.2000	0.0010	4.0000
-17.7195	128.2000	0.0010	4.0000
-18.4390	128.2000	0.0010	4.0000
-19.1586	128.2000	0.0010	4.0000
-19.8781	128.2000	0.0010	4.0000
-20.5976	128.2000	0.0010	4.0000
-21.3171	128.2000	0.0010	4.0000
-22.0367	128.2000	0.0010	4.0000
-22.7562	128.2000	0.0010	4.0000
-23.4757	128.2000	0.0010	4.0000
-24.1952	128.2000	0.0010	4.0000
**********	**********	0.0010	4.0000

BREM ANALYSIS RESULTS

RELATIVE POWER COMPONENTS			RAY ZENITH ANGLES			
POLARIZATION		LINE OF SIGHT	TRANSMITTER		RECEIVER	
VERTICAL DBW	HORIZONTAL DBW	DBW	DIRECT DEGREES	REFLECTED DEGREES	DIRECT DEGREES	REFLECTED DEGREES
-133.	-133.		0.0		0.0	

```
ALL MODE COMEFF INPUT DATA FROM RAYTRACE


        STRESSED TEST RUN AIR TO AIR

         60.       2.0  4.00 11.75  8.74  2.744  2.740    9000.0  151.5  211    12754.8

         60.      22.0  4.00 21.00 29.64  2.991  2.917    9000.0  151.5  211     9335.6

      G  60.     0.0    4.00  0.0   0.0      0.010000.0  10000.0  151.5  211        0.0

      &-132.512    -132.891    -.100000E+76     0.0        0.0       0.0       0.0
&IINIT
NOFREQ=         7,KSW1=          0,KSW2=          1,JCARD=          0,NEWANT=          1,MXANGT=          40,MXANGR=         40,
ANTFIL=         5,P= 3.33300018    ,BAUD= .100000016E-01,PLREJ=  400.000000    ,IBETA=          0,MNANGT=         -40,MNANGR=
    -40,IDEBUG=          0
&END
```

TRANSMITTER GAIN(DB) ANGLE(DEG) BY FREQUENCY(MHZ)

FREQUENCY

	2.0000		3.0000		4.0000		5.0000		7.0000		10.0000		15.0000	
-40	2.60	2.60	1.20	1.60	0.10	0.50	-1.00	-0.50	2.50	5.00	6.00	7.80	3.00	3.90
-39	2.55	2.50	1.02	1.40	-0.10	0.30	-1.13	-0.60	2.30	4.80	5.80	7.60	2.90	3.80
-38	2.49	2.50	0.84	1.20	-0.20	0.20	-1.26	-0.80	2.10	4.60	5.60	7.40	2.70	3.60
-37	2.44	2.40	0.66	1.10	-0.40	0.0	-1.39	-0.90	1.90	4.40	5.50	7.30	2.60	3.50
-36	2.38	2.40	0.48	0.90	-0.60	-0.20	-1.52	-1.00	1.70	4.20	5.30	7.10	2.40	3.30
-35	2.32	2.30	0.30	0.70	-0.70	-0.30	-1.65	-1.20	1.50	4.00	5.10	6.90	2.30	3.20
-34	2.27	2.30	0.12	0.50	-0.90	-0.50	-1.78	-1.30	1.30	3.80	4.90	6.70	2.20	3.10
-33	2.22	2.20	-0.06	0.30	-1.10	-0.70	-1.91	-1.40	1.10	3.60	4.70	6.50	2.00	2.90
-32	2.16	2.20	-0.24	0.20	-1.20	-0.80	-2.04	-1.50	0.90	3.40	4.60	6.40	1.90	2.80
-31	2.10	2.10	-0.42	0.0	-1.40	-1.00	-2.17	-1.70	0.70	3.20	4.40	6.20	1.70	2.60
-30	2.05	2.10	-0.60	-0.20	-1.60	-1.20	-2.30	-1.80	0.50	3.00	4.20	6.00	1.60	2.50
-29	1.99	2.00	-0.78	-0.40	-1.70	-1.30	-2.43	-1.90	0.30	2.80	4.00	5.80	1.50	2.40
-28	1.94	1.90	-0.96	-0.60	-1.90	-1.60	-2.56	-2.10	0.10	2.60	3.80	5.60	1.30	2.20
-27	1.89	1.90	-1.14	-0.70	-2.00	-1.60	-2.69	-2.20	-0.10	2.40	3.70	5.50	1.20	2.10
-26	1.83	1.80	-1.32	-0.90	-2.20	-1.80	-2.82	-2.00	-0.30	2.20	3.50	5.30	1.00	1.90
-25	1.77	1.80	-1.50	-1.10	-2.40	-2.00	-2.95	-2.50	-0.50	2.00	3.30	5.10	0.90	1.80
-24	1.72	1.70	-1.68	-1.30	-2.50	-2.10	-3.08	-2.60	-0.70	1.80	3.10	4.90	0.80	1.70
-23	1.66	1.70	-1.86	-1.50	-2.70	-2.30	-3.21	-2.70	-0.90	1.60	2.90	4.70	0.60	1.50
-22	1.61	1.60	-2.04	-1.60	-2.90	-2.50	-3.34	-2.80	-1.10	1.40	2.80	4.60	0.50	1.40
-21	1.56	1.60	-2.22	-1.80	-3.00	-2.60	-3.47	-3.00	-1.30	1.20	2.60	4.40	0.30	1.20
-20	1.50	1.50	-2.40	-2.00	-3.20	-2.80	-3.60	-3.10	-1.50	1.00	2.40	4.20	0.20	1.10
-19	1.45	1.50	-2.71	-2.30	-3.40	-3.00	-3.72	-3.20	-1.70	0.90	2.20	4.00	-0.10	0.80
-18	1.40	1.40	-3.02	-2.60	-3.60	-3.20	-3.84	-3.30	-1.80	0.70	1.90	3.70	-0.40	0.50
-17	1.35	1.40	-3.33	-2.90	-3.80	-3.40	-3.96	-3.50	-2.00	0.60	1.70	3.50	-0.80	0.10
-16	1.30	1.30	-3.64	-3.20	-4.00	-3.60	-4.08	-3.60	-2.10	0.40	1.40	3.20	-1.10	-0.20
-15	1.25	1.30	-3.95	-3.60	-4.20	-3.80	-4.20	-3.70	-2.30	0.30	1.20	3.00	-1.40	-0.50
-14	1.20	1.20	-4.26	-3.90	-4.40	-4.00	-4.32	-3.80	-2.40	0.10	1.00	2.80	-1.70	-0.80
-13	1.15	1.20	-4.57	-4.20	-4.60	-4.20	-4.44	-3.90	-2.60	-0.10	0.70	2.50	-2.00	-1.10
-12	1.10	1.10	-4.88	-4.50	-4.80	-4.40	-4.56	-4.10	-2.70	-0.20	0.50	2.30	-2.40	-1.50
-11	1.05	1.00	-5.19	-4.80	-5.00	-4.60	-4.68	-4.20	-2.90	-0.40	0.20	2.00	-2.70	-1.80
-10	1.00	1.00	-5.50	-5.10	-5.20	-4.80	-4.80	-4.30	-3.00	-0.50	0.0	1.80	-3.00	-2.10
-9	0.80	0.80	-6.00	-5.60	-5.56	-5.10	-4.80	-4.30	-3.20	-0.70	-0.40	1.40	-3.40	-2.50
-8	0.60	0.60	-6.50	-6.10	-5.92	-5.50	-4.80	-4.30	-3.40	-0.90	-0.80	1.00	-3.90	-3.00
-7	0.40	0.40	-7.00	-6.60	-6.28	-5.90	-4.80	-4.30	-3.60	-1.10	-1.20	0.60	-4.30	-3.40
-6	0.20	0.20	-7.50	-7.10	-6.64	-6.20	-4.80	-4.30	-3.80	-1.30	-1.60	0.20	-4.80	-3.90
-5	0.0	0.0	-8.00	-7.60	-7.00	-6.60	-4.80	-4.30	-4.00	-1.50	-2.00	-0.20	-5.20	-4.30
-4	-0.20	-0.20	-8.50	-8.10	-7.36	-7.00	-4.80	-4.30	-4.20	-1.70	-2.40	-0.60	-5.60	-4.70
-3	-0.40	-0.40	-9.00	-8.60	-7.72	-7.30	-4.80	-4.30	-4.40	-1.90	-2.80	-1.00	-6.10	-5.20
-2	-0.60	-0.60	-9.50	-9.10	-8.08	-7.60	-4.80	-4.30	-4.60	-2.10	-3.20	-1.40	-6.50	-5.60

-1	-0.80	-0.80	-10.00	-9.60	-8.44	-8.00	-4.80	-4.30	-4.80	-2.30	-3.60	-1.80	-7.00	-6.10
0	-1.00	-1.00	-10.50	-10.10	-8.80	-8.40	-4.80	-4.30	-5.00	-2.50	-4.00	-2.20	-7.40	-6.50
1	-0.80	-0.80	-10.00	-9.60	-8.40	-8.00	-4.80	-4.30	-4.80	-2.30	-3.60	-1.80	-7.00	-6.10
2	-0.60	-0.60	-9.50	-9.10	-8.10	-7.60	-4.80	-4.30	-4.60	-2.10	-3.20	-1.40	-6.50	-5.60
3	-0.40	-0.40	-9.00	-8.60	-7.70	-7.30	-4.80	-4.30	-4.40	-1.90	-2.80	-1.00	-6.10	-5.20
4	-0.20	-0.20	-8.50	-8.10	-7.40	-7.00	-4.80	-4.30	-4.20	-1.70	-2.40	-0.60	-5.60	-4.70
5	0.0	0.0	-8.00	-7.60	-7.00	-6.60	-4.80	-4.30	-4.00	-1.50	-2.00	-0.20	-5.20	-4.30
6	0.20	0.20	-7.50	-7.10	-6.60	-6.20	-4.80	-4.30	-3.80	-1.30	-1.60	0.20	-4.80	-3.90
7	0.40	0.40	-7.00	-6.60	-6.30	-5.90	-4.80	-4.30	-3.60	-1.10	-1.20	0.60	-4.30	-3.40
8	0.60	0.60	-6.50	-6.10	-5.90	-5.50	-4.80	-4.30	-3.40	-0.90	-0.80	1.00	-3.90	-3.00
9	0.80	0.80	-6.00	-5.60	-5.60	-5.10	-4.80	-4.30	-3.20	-0.70	-0.40	1.40	-3.40	-2.50
10	1.00	1.00	-5.50	-5.10	-5.20	-4.80	-4.80	-4.30	-3.00	-0.50	0.0	1.80	-3.00	-2.10
11	1.00	1.00	-5.20	-4.80	-5.00	-4.60	-4.70	-4.20	-2.90	-0.40	0.20	2.00	-2.70	-1.80
12	1.10	1.10	-4.90	-4.50	-4.80	-4.40	-4.60	-4.10	-2.70	-0.20	0.50	2.30	-2.40	-1.50
13	1.20	1.20	-4.60	-4.20	-4.60	-4.20	-4.40	-3.90	-2.60	-0.10	0.70	2.50	-2.00	-1.10
14	1.20	1.20	-4.30	-3.90	-4.40	-4.00	-4.30	-3.80	-2.40	0.10	1.00	2.80	-1.70	-0.80
15	1.30	1.30	-4.00	-3.60	-4.20	-3.80	-4.20	-3.70	-2.30	0.30	1.20	3.00	-1.40	-0.50
16	1.30	1.30	-3.60	-3.20	-4.00	-3.60	-4.10	-3.60	-2.10	0.40	1.40	3.20	-1.10	-0.20
17	1.40	1.40	-3.30	-2.90	-3.80	-3.40	-4.00	-3.50	-2.00	0.60	1.70	3.50	-0.80	0.10
18	1.40	1.40	-3.00	-2.60	-3.60	-3.20	-3.80	-3.30	-1.80	0.70	1.90	3.70	-0.40	0.50
19	1.50	1.50	-2.70	-2.30	-3.40	-3.00	-3.70	-3.20	-1.70	0.90	2.20	4.00	-0.10	0.80
20	1.50	1.50	-2.40	-2.00	-3.20	-2.80	-3.60	-3.10	-1.50	1.00	2.40	4.20	0.20	1.10
21	1.60	1.60	-2.20	-1.80	-3.00	-2.60	-3.50	-3.00	-1.30	1.20	2.60	4.40	0.30	1.20
22	1.60	1.60	-2.00	-1.60	-2.90	-2.50	-3.30	-2.80	-1.10	1.40	2.80	4.60	0.50	1.40
23	1.70	1.70	-1.90	-1.50	-2.70	-2.30	-3.20	-2.70	-0.90	1.60	2.90	4.70	0.60	1.50
24	1.70	1.70	-1.70	-1.30	-2.50	-2.10	-3.10	-2.60	-0.70	1.80	3.10	4.90	0.80	1.70
25	1.80	1.80	-1.50	-1.10	-2.40	-2.00	-3.00	-2.50	-0.50	2.00	3.30	5.10	0.90	1.80
26	1.80	1.80	-1.30	-0.90	-2.20	-1.80	-2.80	-2.00	-0.30	2.20	3.50	5.30	1.00	1.90
27	1.90	1.90	-1.10	-0.70	-2.00	-1.60	-2.70	-2.20	-0.10	2.40	3.70	5.50	1.20	2.10
28	1.90	1.90	-1.00	-0.60	-1.90	-1.60	-2.60	-2.10	0.10	2.60	3.80	5.60	1.30	2.20
29	2.00	2.00	-0.80	-0.40	-1.70	-1.30	-2.40	-1.90	0.30	2.80	4.00	5.80	1.50	2.40
30	2.10	2.10	-0.60	-0.20	-1.60	-1.20	-2.30	-1.80	0.50	3.00	4.20	6.00	1.60	2.50
31	2.10	2.10	-0.40	0.0	-1.40	-1.00	-2.20	-1.70	0.70	3.20	4.40	6.20	1.70	2.60
32	2.20	2.20	-0.20	0.20	-1.20	-0.80	-2.00	-1.50	0.90	3.40	4.60	6.40	1.90	2.80
33	2.20	2.20	-0.10	0.30	-1.10	-0.70	-1.90	-1.40	1.10	3.60	4.70	6.50	2.00	2.90
34	2.30	2.30	0.10	0.50	-0.90	-0.50	-1.80	-1.30	1.30	3.80	4.90	6.70	2.20	3.10
35	2.30	2.30	0.30	0.70	-0.70	-0.30	-1.70	-1.20	1.50	4.00	5.10	6.90	2.30	3.20
36	2.40	2.40	0.50	0.90	-0.60	-0.20	-1.50	-1.00	1.70	4.20	5.30	7.10	2.40	3.30
37	2.40	2.40	0.70	1.10	-0.40	0.0	-1.40	-0.90	1.90	4.40	5.50	7.30	2.60	3.50
38	2.50	2.50	0.80	1.20	-0.20	0.20	-1.30	-0.80	2.10	4.60	5.60	7.40	2.70	3.60
39	2.50	2.50	1.00	1.40	-0.10	0.30	-1.10	-0.60	2.30	4.80	5.80	7.60	2.90	3.80
40	2.60	2.60	1.20	1.60	0.10	0.50	-1.00	-0.50	2.50	5.00	6.00	7.80	3.00	3.90

RECEIVER GAIN(DB) ANGLE(DEG) BY FREQUENCY(MHZ)
FREQUENCY

	2.0000		3.0000		4.0000		5.0000		7.0000		10.0000		15.0000	
-40	2.60	2.60	1.20	1.60	0.10	0.50	-1.00	-0.50	2.50	5.00	6.00	7.80	3.00	3.90
-39	2.55	2.50	1.02	1.40	-0.10	0.30	-1.13	-0.60	2.30	4.80	5.80	7.60	2.90	3.80
-38	2.49	2.50	0.84	1.20	-0.20	0.20	-1.26	-0.80	2.10	4.60	5.60	7.40	2.70	3.60
-37	2.44	2.40	0.66	1.10	-0.40	0.0	-1.39	-0.90	1.90	4.40	5.50	7.30	2.60	3.50
-36	2.38	2.40	0.48	0.90	-0.60	-0.20	-1.52	-1.00	1.70	4.20	5.30	7.10	2.40	3.30
-35	2.32	2.30	0.30	0.70	-0.70	-0.30	-1.65	-1.20	1.50	4.00	5.10	6.90	2.30	3.20
-34	2.27	2.30	0.12	0.50	-0.90	-0.50	-1.78	-1.30	1.30	3.80	4.90	6.70	2.20	3.10
-33	2.22	2.20	-0.06	0.30	-1.10	-0.70	-1.91	-1.40	1.10	3.60	4.70	6.50	2.00	2.90
-32	2.16	2.20	-0.24	0.20	-1.20	-0.80	-2.04	-1.50	0.90	3.40	4.60	6.40	1.90	2.80
-31	2.10	2.10	-0.42	0.0	-1.40	-1.00	-2.17	-1.70	0.70	3.20	4.40	6.20	1.70	2.60
-30	2.05	2.10	-0.60	-0.20	-1.60	-1.20	-2.30	-1.80	0.50	3.00	4.20	6.00	1.60	2.50
-29	1.99	2.00	-0.78	-0.40	-1.70	-1.30	-2.43	-1.90	0.30	2.80	4.00	5.80	1.50	2.40
-28	1.94	1.90	-0.96	-0.60	-1.90	-1.60	-2.56	-2.10	0.10	2.60	3.80	5.60	1.30	2.20
-27	1.89	1.90	-1.14	-0.70	-2.00	-1.60	-2.69	-2.20	-0.10	2.40	3.70	5.50	1.20	2.10
-26	1.83	1.80	-1.32	-0.90	-2.20	-1.80	-2.82	-2.00	-0.30	2.20	3.50	5.30	1.00	1.90
-25	1.77	1.80	-1.50	-1.10	-2.40	-2.00	-2.95	-2.50	-0.50	2.00	3.30	5.10	0.90	1.80
-24	1.72	1.70	-1.68	-1.30	-2.50	-2.10	-3.08	-2.60	-0.70	1.80	3.10	4.90	0.80	1.70
-23	1.66	1.70	-1.86	-1.50	-2.70	-2.30	-3.21	-2.70	-0.90	1.60	2.90	4.70	0.60	1.50

-22	1.61	1.60	-2.04	-1.60	-2.90	-2.50	-3.34	-2.80	-1.10	1.40	2.80	4.60	0.50	1.40
-21	1.56	1.60	-2.22	-1.80	-3.00	-2.60	-3.47	-3.00	-1.30	1.20	2.60	4.40	0.30	1.20
-20	1.50	1.50	-2.40	-2.00	-3.20	-2.80	-3.60	-3.10	-1.50	1.00	2.40	4.20	0.20	1.10
-19	1.45	1.50	-2.71	-2.30	-3.40	-3.00	-3.72	-3.20	-1.70	0.90	2.20	4.00	-0.10	0.80
-18	1.40	1.40	-3.02	-2.60	-3.60	-3.20	-3.84	-3.30	-1.80	0.70	1.90	3.70	-0.40	0.50
-17	1.35	1.40	-3.33	-2.90	-3.80	-3.40	-3.96	-3.50	-2.00	0.60	1.70	3.50	-0.80	0.10
-16	1.30	1.30	-3.64	-3.20	-4.00	-3.60	-4.08	-3.60	-2.10	0.40	1.40	3.20	-1.10	-0.20
-15	1.25	1.30	-3.95	-3.60	-4.20	-3.80	-4.20	-3.70	-2.30	0.30	1.20	3.00	-1.40	-0.50
-14	1.20	1.20	-4.26	-3.90	-4.40	-4.00	-4.32	-3.80	-2.40	0.10	1.00	2.80	-1.70	-0.80
-13	1.15	1.20	-4.57	-4.20	-4.60	-4.20	-4.44	-3.90	-2.60	-0.10	0.70	2.50	-2.00	-1.10
-12	1.10	1.10	-4.88	-4.50	-4.80	-4.40	-4.56	-4.10	-2.70	-0.20	0.50	2.30	-2.40	-1.50
-11	1.05	1.00	-5.19	-4.80	-5.00	-4.60	-4.68	-4.20	-2.90	-0.40	0.20	2.00	-2.70	-1.80
-10	1.00	1.00	-5.50	-5.10	-5.20	-4.80	-4.80	-4.30	-3.00	-0.50	0.0	1.80	-3.00	-2.10
-9	0.80	0.80	-6.00	-5.60	-5.56	-5.10	-4.80	-4.30	-3.20	-0.70	-0.40	1.40	-3.40	-2.50
-8	0.60	0.60	-6.50	-6.10	-5.92	-5.50	-4.80	-4.30	-3.40	-0.90	-0.80	1.00	-3.90	-3.00
-7	0.40	0.40	-7.00	-6.60	-6.28	-5.90	-4.80	-4.30	-3.60	-1.10	-1.20	0.60	-4.30	-3.40
-6	0.20	0.20	-7.50	-7.10	-6.64	-6.20	-4.80	-4.30	-3.80	-1.30	-1.60	0.20	-4.80	-3.90
-5	0.0	0.0	-8.00	-7.60	-7.00	-6.60	-4.80	-4.30	-4.00	-1.50	-2.00	-0.20	-5.20	-4.30
-4	-0.20	-0.20	-8.50	-8.10	-7.36	-7.00	-4.80	-4.30	-4.20	-1.70	-2.40	-0.60	-5.60	-4.70
-3	-0.40	-0.40	-9.00	-8.60	-7.72	-7.30	-4.80	-4.30	-4.40	-1.90	-2.80	-1.00	-6.10	-5.20
-2	-0.60	-0.60	-9.50	-9.10	-8.08	-7.60	-4.80	-4.30	-4.60	-2.10	-3.20	-1.40	-6.50	-5.60
-1	-0.80	-0.80	-10.00	-9.60	-8.44	-8.00	-4.80	-4.30	-4.80	-2.30	-3.60	-1.80	-7.00	-6.10
0	-1.00	-1.00	-10.50	-10.10	-8.80	-8.40	-4.80	-4.30	-5.00	-2.50	-4.00	-2.20	-7.40	-6.50
1	-0.80	-0.80	-10.00	-9.60	-8.40	-8.00	-4.80	-4.30	-4.80	-2.30	-3.60	-1.80	-7.00	-6.10
2	-0.60	-0.60	-9.50	-9.10	-8.10	-7.60	-4.80	-4.30	-4.60	-2.10	-3.20	-1.40	-6.50	-5.60
3	-0.40	-0.40	-9.00	-8.60	-7.70	-7.30	-4.80	-4.30	-4.40	-1.90	-2.80	-1.00	-6.10	-5.20
4	-0.20	-0.20	-8.50	-8.10	-7.40	-7.00	-4.80	-4.30	-4.20	-1.70	-2.40	-0.60	-5.60	-4.70
5	0.0	0.0	-8.00	-7.60	-7.00	-6.60	-4.80	-4.30	-4.00	-1.50	-2.00	-0.20	-5.20	-4.30
6	0.20	0.20	-7.50	-7.10	-6.60	-6.20	-4.80	-4.30	-3.80	-1.30	-1.60	0.20	-4.80	-3.90
7	0.40	0.40	-7.00	-6.60	-6.30	-5.90	-4.80	-4.30	-3.60	-1.10	-1.20	0.60	-4.30	-3.40
8	0.60	0.60	-6.50	-6.10	-5.90	-5.50	-4.80	-4.30	-3.40	-0.90	-0.80	1.00	-3.90	-3.00
9	0.80	0.80	-6.00	-5.60	-5.60	-5.10	-4.80	-4.30	-3.20	-0.70	-0.40	1.40	-3.40	-2.50
10	1.00	1.00	-5.50	-5.10	-5.20	-4.80	-4.80	-4.30	-3.00	-0.50	0.0	1.80	-3.00	-2.10
11	1.00	1.00	-5.20	-4.80	-5.00	-4.60	-4.70	-4.20	-2.90	-0.40	0.20	2.00	-2.70	-1.80
12	1.10	1.10	-4.90	-4.50	-4.80	-4.40	-4.60	-4.10	-2.70	-0.20	0.50	2.30	-2.40	-1.50
13	1.20	1.20	-4.60	-4.20	-4.60	-4.20	-4.40	-3.90	-2.60	-0.10	0.70	2.50	-2.00	-1.10
14	1.20	1.20	-4.30	-3.90	-4.40	-4.00	-4.30	-3.80	-2.40	0.10	1.00	2.80	-1.70	-0.80
15	1.30	1.30	-4.00	-3.60	-4.20	-3.80	-4.20	-3.70	-2.30	0.30	1.20	3.00	-1.40	-0.50
16	1.30	1.30	-3.60	-3.20	-4.00	-3.60	-4.10	-3.60	-2.10	0.40	1.40	3.20	-1.10	-0.20
17	1.40	1.40	-3.30	-2.90	-3.80	-3.40	-4.00	-3.50	-2.00	0.60	1.70	3.50	-0.80	0.10
18	1.40	1.40	-3.00	-2.60	-3.60	-3.20	-3.80	-3.30	-1.80	0.70	1.90	3.70	-0.40	0.50
19	1.50	1.50	-2.70	-2.30	-3.40	-3.00	-3.70	-3.20	-1.70	0.90	2.20	4.00	-0.10	0.80
20	1.50	1.50	-2.40	-2.00	-3.20	-2.80	-3.60	-3.10	-1.50	1.00	2.40	4.20	0.20	1.10
21	1.60	1.60	-2.20	-1.80	-3.00	-2.60	-3.50	-3.00	-1.30	1.20	2.60	4.40	0.30	1.20
22	1.60	1.60	-2.00	-1.60	-2.90	-2.50	-3.30	-2.80	-1.10	1.40	2.80	4.60	0.50	1.40
23	1.70	1.70	-1.90	-1.50	-2.70	-2.30	-3.20	-2.70	-0.90	1.60	2.90	4.70	0.60	1.50
24	1.70	1.70	-1.70	-1.30	-2.50	-2.10	-3.10	-2.60	-0.70	1.80	3.10	4.90	0.80	1.70
25	1.80	1.80	-1.50	-1.10	-2.40	-2.00	-3.00	-2.50	-0.50	2.00	3.30	5.10	0.90	1.80
26	1.80	1.80	-1.30	-0.90	-2.20	-1.80	-2.80	-2.00	-0.30	2.20	3.50	5.30	1.00	1.90
27	1.90	1.90	-1.10	-0.70	-2.00	-1.60	-2.70	-2.20	-0.10	2.40	3.70	5.50	1.20	2.10
28	1.90	1.90	-1.00	-0.60	-1.90	-1.60	-2.60	-2.10	0.10	2.60	3.80	5.60	1.30	2.20
29	2.00	2.00	-0.80	-0.40	-1.70	-1.30	-2.40	-1.90	0.30	2.80	4.00	5.80	1.50	2.40
30	2.10	2.10	-0.60	-0.20	-1.60	-1.20	-2.30	-1.80	0.50	3.00	4.20	6.00	1.60	2.50
31	2.10	2.10	-0.40	0.0	-1.40	-1.00	-2.20	-1.70	0.70	3.20	4.40	6.20	1.70	2.60
32	2.20	2.20	-0.20	0.20	-1.20	-0.80	-2.00	-1.50	0.90	3.40	4.60	6.40	1.90	2.80
33	2.20	2.20	-0.10	0.30	-1.10	-0.70	-1.90	-1.40	1.10	3.60	4.70	6.50	2.00	2.90
34	2.30	2.30	0.10	0.50	-0.90	-0.50	-1.80	-1.30	1.30	3.80	4.90	6.70	2.20	3.10
35	2.30	2.30	0.30	0.70	-0.70	-0.30	-1.70	-1.20	1.50	4.00	5.10	6.90	2.30	3.20
36	2.40	2.40	0.50	0.90	-0.60	-0.20	-1.50	-1.00	1.70	4.20	5.30	7.10	2.40	3.30
37	2.40	2.40	0.70	1.10	-0.40	0.0	-1.40	-0.90	1.90	4.40	5.50	7.30	2.60	3.50
38	2.50	2.50	0.80	1.20	-0.20	0.20	-1.30	-0.80	2.10	4.60	5.60	7.40	2.70	3.60
39	2.50	2.50	1.00	1.40	-0.10	0.30	-1.10	-0.60	2.30	4.80	5.80	7.60	2.90	3.80
40	2.60	2.60	1.20	1.60	0.10	0.50	-1.00	-0.50	2.50	5.00	6.00	7.80	3.00	3.90

KSW	DBV	DBH	DBL	TBD	TBR	RBD	RBR
8	-132.512	-132.891	-.100000E+76	.0	.0	.0	.0

DB FROM BREM	P	TRANSMITTER GN	RECEIVER GAIN	COMPENSATED POWER
-132.511993	5.2283525	-8.7999954	-8.7999954	-144.883606
-132.891006	5.2283525	-8.3999968	-8.3999968	-144.462631

****

SIGNAL ANALYSIS INCLUDING BREM ANALYSIS

GROUND OR REFLECTED		DIRECT					
VERTICAL DBW	HORIZONTAL DBW	VERTICAL DBW	HORIZONTAL DBW	IONOSPHERIC SIGNAL SUM DBW	VERTICAL NOISE -DBW	CORRECTED NOISE -DBW	CORRECTED ALL MODE S/N RATIO
-144.884	-144.463	-.100000E+76	-.100000E+76	-.100000E+76	151.500	148.801	7.14290

****

GMT	TIME (SEC)	FREQ	NMODES	MGT (MS)	2*SIGMA (MS)	SIGNAL (-DBW)	S/N (DB)	EFPL (DB)	(S/N)MAX (DB)
211	60.	4.0	2	NO IONOSPHERIC PROPOGATION					

5.6 Sample of Deck Setup

The following listing shows a typical deck setup for NUCOM/BREM.

```
//GOU0T007 JOB (1391310,3126,C,,842),OREGAN,MSGLEVEL=1,
// CLASS=C,TIME=25
// EXEC NATPATS
//NATPATS.SYSIN DD *
      -17.0    -128.2     -24.2    -128.2        6       2.2        20         0
0                                  STRESSED TEST RUN AIR TO AIR BEYOND LOS
/*
// EXEC NUCEFMS
//STEPLIB DD DSN=COLATKL.G000.NUCEFM.A.LMOD,DISP=SHR
//NUCEFMS.SYSIN DD *
1       16         2         0         0         5        .5        1.

2     1.30       70.        .4        .1     -20.0    -128.0        0.
3        2       .75       .01
6       30        35        40        45        50        55        60
6       62        65        68        70        72        75        80
6       85        90        92        96       100       105       115
6      125       135       145       155       165       175       185
6      195       205       215       225       240       255       270
6      285       300       325       350       375       400       425
6      450       500       600       700
7       60
0
 0
/*
//ORDER EXEC PGM=ORDER
//ORDER.SYSIN DD *
  2.5     3        .5     -20.0    -128.0       200      1800    0    0      2000
/*
// EXEC RAYBREM
//STEPLIB DD DSN=U.G000.A9999999.RAYPLUS.V3T2.LMOD,DISP=SHR
//RAYBREM.SYSIN DD *
1        0         0
2    -17.0    -128.2     -24.2    -128.2
3      4.0       1.0       4.0       0.1       1.0      75.0        .6        .6
5        1
6      2.2
7       60
8        0         0         0
9      4.0
0  STRESSED TEST RUN AIR TO AIR
   10000.0   10000.0   0.0       0.0       0.0       10     0
1        0         1
/*
//COMBREM EXEC PGM=COMEFF
//STEPLIB DD DSN=U.G000.A9707702.COMEFF.NEW2.LMOD,DISP=SHR
//FT01F001 DD DSN=&&COMWRK,UNIT=SYSDA,SPACE=(TRK,(5,5)),DISP=(NEW,PASS)
//FT05F001 DD DDNAME=SYSIN
//FT06F001 DD SYSOUT=A
//FT07F001 DD DSN=&&COMINP,DISP=(OLD,DELETE)
//FT09F001 DD DSN=ANTENNA.FILE.DATA,DISP=SHR
//COMBREM.SYSIN DD *
 &INIT KSW1=0,KSW2=1,MNANGT=-40,MXANGT=40,MNANGR=-40,MXANGR=40,
 NOFREQ=7,PLREQ=400,,NEWANT=1  &END
PRNT     1
  2.0  3.0  4.0  5.0  7.0  10.0 15.0
  -402,6001.200  0.1-1.00  2.5  6.0  3.0  1.2
  -40  2.6  1.6  0.5 -0.5  5.0  7.8  3.9  3.1
  -392,545 1.02 -0.1-1.13  2.3  5.8  2.9  1.2
  -39  2.5  1.4  0.3 -0.6  4.8  7.6  3.8  3.1
```

```
0061:   -382.490 0.84 -0.2-1.26  2.1  5.6  2.7  1.1
0062:   -38  2.5  1.2  0.2 -0.8  4.6  7.4  3.6  3.0
0063:   -372.435 0.66 -0.4-1.39  1.9  5.5  2.6  1.1
0064:   -37  2.4  1.1 -0.0 -0.9  4.4  7.3  3.5  3.0
0065:   -362.380 0.48 -0.6-1.52  1.7  5.3  2.4  1.0
0066:   -36  2.4  0.9 -0.2 -1.0  4.2  7.1  3.3  2.9
0067:   -352.325 0.30 -0.7-1.65  1.5  5.1  2.3  1.0
0068:   -35  2.3  0.7 -0.3 -1.2  4.0  6.9  3.2  2.9
0069:   -342.270 0.12 -0.9-1.78  1.3  4.9  2.2  1.0
0070:   -34  2.3  0.5 -0.5 -1.3  3.8  6.7  3.1  2.9
0071:   -332.215-0.06 -1.1-1.91  1.1  4.7  2.0  0.9
0072:   -33  2.2  0.3 -0.7 -1.4  3.6  6.5  2.9  2.8
0073:   -322.160-0.24 -1.2-2.04  0.9  4.6  1.9  0.9
0074:   -32  2.2  0.2 -0.8 -1.5  3.4  6.4  2.8  2.8
0075:   -312.105-0.42 -1.4-2.17  0.7  4.4  1.7  0.8
0076:   -31  2.1  0.0 -1.0 -1.7  3.2  6.2  2.6  2.7
0077:   -302.050-0.60 -1.6-2.30  0.5  4.2  1.6  0.8
0078:   -30  2.1 -0.2 -1.2 -1.8  3.0  6.0  2.5  2.7
0079:   -291.995-0.78 -1.7-2.43  0.3  4.0  1.5  0.8
0080:   -29  2.0 -0.4 -1.3 -1.9  2.8  5.8  2.4  2.7
0081:   -281.940-0.96 -1.9-2.56  0.1  3.8  1.3  0.7
0082:   -28  1.9 -0.6 -1.6 -2.1  2.6  5.6  2.2  2.6
0083:   -271.885-1.14 -2.0-2.69 -0.1  3.7  1.2  0.7
0084:   -27  1.9 -0.7 -1.6 -2.2  2.4  5.5  2.1  2.6
0085:   -261.830-1.32 -2.2-2.82 -0.3  3.5  1.0  0.6
0086:   -26  1.8 -0.9 -1.8 -2.0  2.2  5.3  1.9  2.5
0087:   -251.775-1.50 -2.4-2.95 -0.5  3.3  0.9  0.6
0088:   -25  1.8 -1.1 -2.0 -2.5  2.0  5.1  1.8  2.5
0089:   -241.720-1.68 -2.5-3.08 -0.7  3.1  0.8  0.6
0090:   -24  1.7 -1.3 -2.1 -2.6  1.8  4.9  1.7  2.5
0091:   -231.665-1.86 -2.7-3.21 -0.9  2.9  0.6  0.5
0092:   -23  1.7 -1.5 -2.3 -2.7  1.6  4.7  1.5  2.4
0093:   -221.610-2.04 -2.9-3.34 -1.1  2.8  0.5  0.5
0094:   -22  1.6 -1.6 -2.5 -2.8  1.4  4.6  1.4  2.4
0095:   -211.555-2.22 -3.0-3.47 -1.3  2.6  0.3  0.4
0096:   -21  1.6 -1.8 -2.6 -3.0  1.2  4.4  1.2  2.3
0097:   -20 1.50-2.40 -3.2-3.60 -1.5  2.4  0.2  0.4
0098:   -20  1.5 -2.0 -2.8 -3.1  1.0  4.2  1.1  2.3
0099:   -19 1.45-2.71 -3.4-3.72 -1.7  2.2 -0.1  0.3
0100:   -19  1.5 -2.3 -3.0 -3.2  0.9  4.0  0.8  2.2
0101:   -18 1.40-3.02 -3.6-3.84 -1.8  1.9 -0.4  0.1
0102:   -18  1.4 -2.6 -3.2 -3.3  0.7  3.7  0.5  2.0
0103:   -17 1.35-3.33 -3.8-3.96 -2.0  1.7 -0.8  0.0
0104:   -17  1.4 -2.9 -3.4 -3.5  0.6  3.5  0.1  1.9
0105:   -16 1.30-3.64 -4.0-4.08 -2.1  1.4 -1.1 -0.2
0106:   -16  1.3 -3.2 -3.6 -3.6  0.4  3.2 -0.2  1.7
0107:   -15 1.25-3.95 -4.2-4.20 -2.3  1.2 -1.4 -0.3
0108:   -15  1.3 -3.6 -3.8 -3.7  0.3  3.0 -0.5  1.6
0109:   -14 1.20-4.26 -4.4-4.32 -2.4  1.0 -1.7 -0.4
0110:   -14  1.2 -3.9 -4.0 -3.8  0.1  2.8 -0.8  1.5
0111:   -13 1.15-4.57 -4.6-4.44 -2.6  0.7 -2.0 -0.6
0112:   -13  1.2 -4.2 -4.2 -3.9 -0.1  2.5 -1.1  1.3
0113:   -12 1.10-4.88 -4.8-4.56 -2.7  0.5 -2.4 -0.7
0114:   -12  1.1 -4.5 -4.4 -4.1 -0.2  2.3 -1.5  1.2
0115:   -11 1.05-5.19 -5.0-4.68 -2.9  0.2 -2.7 -0.9
0116:   -11  1.0 -4.8 -4.6 -4.2 -0.4  2.0 -1.8  1.0
0117:   -10  1.0-5.50-5.20-4.80 -3.0  0.0 -3.0 -1.0
0118:   -10  1.0 -5.1 -4.8 -4.3 -0.5  1.8 -2.1  0.9
0119:    -9  0.8 -6.0-5.56-4.80 -3.2 -0.4 -3.4 -1.2
0120:    -9  0.8 -5.6 -5.1 -4.3 -0.7  1.4 -2.5  0.7
```

0121:	-8	0.6	-6.5	-5.92	-4.80	-3.4	-0.8	-3.9	-1.5
0122:	-8	0.6	-6.1	-5.5	-4.3	-0.9	1.0	-3.0	0.4
0123:	-7	0.4	-7.0	-6.28	-4.80	-3.6	-1.2	-4.3	-1.7
0124:	-7	0.4	-6.6	-5.9	-4.3	-1.1	0.6	-3.4	0.2
0125:	-6	0.2	-7.5	-6.64	-4.80	-3.8	-1.6	-4.8	-2.0
0126:	-6	0.2	-7.1	-6.2	-4.3	-1.3	0.2	-3.9	-0.1
0127:	-5	0.0	-8.0	-7.00	-4.80	-4.0	-2.0	-5.2	-2.2
0128:	-5	0.0	-7.6	-6.6	-4.3	-1.5	-0.2	-4.3	-0.3
0129:	-4	-0.2	-8.5	-7.36	-4.80	-4.2	-2.4	-5.6	-2.4
0130:	-4	-0.2	-8.1	-7.0	-4.3	-1.7	-0.6	-4.7	-0.5
0131:	-3	-0.4	-9.0	-7.72	-4.80	-4.4	-2.8	-6.1	-2.7
0132:	-3	-0.4	-8.6	-7.3	-4.3	-1.9	-1.0	-5.2	-0.8
0133:	-2	-0.6	-9.5	-8.08	-4.80	-4.6	-3.2	-6.5	-2.9
0134:	-2	-0.6	-9.1	-7.6	-4.3	-2.1	-1.4	-5.6	-1.0
0135:	-1	-0.8	-10.0	-8.44	-4.80	-4.8	-3.6	-7.0	-3.2
0136:	-1	-0.8	-9.6	-8.0	-4.3	-2.3	-1.8	-6.1	-1.3
0137:	0	-1.0	-10.5	-8.8	-4.8	-5.0	-4.0	-7.4	-3.4
0138:	0	-1.0	-10.1	-8.4	-4.3	-2.5	-2.2	-6.5	-1.5
0139:	1	-0.8	-10.0	-8.4	-4.8	-4.8	-3.6	-7.0	-3.2
0140:	1	-0.8	-9.6	-8.0	-4.3	-2.3	-1.8	-6.1	-1.3
0141:	2	-0.6	-9.5	-8.1	-4.8	-4.6	-3.2	-6.5	-2.9
0142:	2	-0.6	-9.1	-7.6	-4.3	-2.1	-1.4	-5.6	-1.0
0143:	3	-0.4	-9.0	-7.7	-4.8	-4.4	-2.8	-6.1	-2.7
0144:	3	-0.4	-8.6	-7.3	-4.3	-1.9	-1.0	-5.2	-0.8
0145:	4	-0.2	-8.5	-7.4	-4.8	-4.2	-2.4	-5.6	-2.4
0146:	4	-0.2	-8.1	-7.0	-4.3	-1.7	-0.6	-4.7	-0.5
0147:	5	0.0	-8.0	-7.0	-4.8	-4.0	-2.0	-5.2	-2.2
0148:	5	0.0	-7.6	-6.6	-4.3	-1.5	-0.2	-4.3	-0.3
0149:	6	0.2	-7.5	-6.6	-4.8	-3.8	-1.6	-4.8	-2.0
0150:	6	0.2	-7.1	-6.2	-4.3	-1.3	0.2	-3.9	-0.1
0151:	7	0.4	-7.0	-6.3	-4.8	-3.6	-1.2	-4.3	-1.[illegible]
0152:	7	0.4	-6.6	-5.9	-4.3	-1.1	0.6	-3.4	0.2
0153:	8	0.6	-6.5	-5.9	-4.8	-3.4	-0.8	-3.9	-1.5
0154:	8	0.6	-6.1	-5.5	-4.3	-0.9	1.0	-3.0	0.4
0155:	9	0.8	-6.0	-5.6	-4.8	-3.2	-0.4	-3.4	-1.2
0156:	9	0.8	-5.6	-5.1	-4.3	-0.7	1.4	-2.5	0.7
0157:	10	1.0	-5.5	-5.2	-4.8	-3.0	0.0	-3.0	-1.0
0158:	10	1.0	-5.1	-4.8	-4.3	-0.5	1.8	-2.1	0.9
0159:	11	1.0	-5.2	-5.0	-4.7	-2.9	0.2	-2.7	-0.9
0160:	11	1.0	-4.8	-4.6	-4.2	-0.4	2.0	-1.8	1.0
0161:	12	1.1	-4.9	-4.8	-4.6	-2.7	0.5	-2.4	-0.7
0162:	12	1.1	-4.5	-4.4	-4.1	-0.2	2.3	-1.5	1.2
0163:	13	1.2	-4.6	-4.6	-4.4	-2.6	0.7	-2.0	-0.6
0164:	13	1.2	-4.2	-4.2	-3.9	-0.1	2.5	-1.1	1.3
0165:	14	1.2	-4.3	-4.4	-4.3	-2.4	1.0	-1.7	-0.4
0166:	14	1.2	-3.9	-4.0	-3.8	0.1	2.8	-0.8	1.5
0167:	15	1.3	-4.0	-4.2	-4.2	-2.3	1.2	-1.4	-0.3
0168:	15	1.3	-3.6	-3.8	-3.7	0.3	3.0	-0.5	1.6
0169:	16	1.3	-3.6	-4.0	-4.1	-2.1	1.4	-1.1	-0.2
0170:	16	1.3	-3.2	-3.6	-3.6	0.4	3.2	-0.2	1.7
0171:	17	1.4	-3.3	-3.8	-4.0	-2.0	1.7	-0.8	0.0
0172:	17	1.4	-2.9	-3.4	-3.5	0.6	3.5	0.1	1.9
0173:	18	1.4	-3.0	-3.6	-3.8	-1.8	1.9	-0.4	0.1
0174:	18	1.4	-2.6	-3.2	-3.3	0.7	3.7	0.5	2.0
0175:	19	1.5	-2.7	-3.4	-3.7	-1.7	2.2	-0.1	0.3
0176:	19	1.5	-2.3	-3.0	-3.2	0.9	4.0	0.8	2.2
0177:	20	1.5	-2.4	-3.2	-3.6	-1.5	2.4	0.2	0.4
0178:	20	1.5	-2.0	-2.8	-3.1	1.0	4.2	1.1	2.3
0179:	21	1.6	-2.2	-3.0	-3.5	-1.3	2.6	0.3	0.4
0180:	21	1.6	-1.8	-2.6	-3.0	1.2	4.4	1.2	2.3

0181:	22	1.6	-2.0	-2.9	-3.3	-1.1	2.8	0.5	0.5
0182:	22	1.6	-1.6	-2.5	-2.8	1.4	4.6	1.4	2.4
0183:	23	1.7	-1.9	-2.7	-3.2	-0.9	2.9	0.6	0.5
0184:	23	1.7	-1.5	-2.3	-2.7	1.6	4.7	1.5	2.4
0185:	24	1.7	-1.7	-2.5	-3.1	-0.7	3.1	0.8	0.6
0186:	24	1.7	-1.3	-2.1	-2.6	1.8	4.9	1.7	2.5
0187:	25	1.8	-1.5	-2.4	-3.0	-0.5	3.3	0.9	0.6
0188:	25	1.8	-1.1	-2.0	-2.5	2.0	5.1	1.8	2.5
0189:	26	1.8	-1.3	-2.2	-2.8	-0.3	3.5	1.0	0.6
0190:	26	1.8	-0.9	-1.8	-2.0	2.2	5.3	1.9	2.5
0191:	27	1.9	-1.1	-2.0	-2.7	-0.1	3.7	1.2	0.7
0192:	27	1.9	-0.7	-1.6	-2.2	2.4	5.5	2.1	2.6
0193:	28	1.9	-1.0	-1.9	-2.6	0.1	3.8	1.3	0.7
0194:	28	1.9	-0.6	-1.6	-2.1	2.6	5.6	2.2	2.6
0195:	29	2.0	-0.8	-1.7	-2.4	0.3	4.0	1.5	0.8
0196:	29	2.0	-0.4	-1.3	-1.9	2.8	5.8	2.4	2.7
0197:	30	2.1	-0.6	-1.6	-2.3	0.5	4.2	1.6	0.8
0198:	30	2.1	-0.2	-1.2	-1.8	3.0	6.0	2.5	2.7
0199:	31	2.1	-0.4	-1.4	-2.2	0.7	4.4	1.7	0.8
0200:	31	2.1	0.0	-1.0	-1.7	3.2	6.2	2.6	2.7
0201:	32	2.2	-0.2	-1.2	-2.0	0.9	4.6	1.9	0.9
0202:	32	2.2	0.2	-0.8	-1.5	3.4	6.4	2.8	2.8
0203:	33	2.2	-0.1	-1.1	-1.9	1.1	4.7	2.0	0.9
0204:	33	2.2	0.3	-0.7	-1.4	3.6	6.5	2.9	2.8
0205:	34	2.3	0.1	-0.9	-1.8	1.3	4.9	2.2	1.0
0206:	34	2.3	0.5	-0.5	-1.3	3.8	6.7	3.1	2.9
0207:	35	2.3	0.3	-0.7	-1.7	1.5	5.1	2.3	1.0
0208:	35	2.3	0.7	-0.3	-1.2	4.0	6.9	3.2	2.9
0209:	36	2.4	0.5	-0.6	-1.5	1.7	5.3	2.4	1.0
0210:	36	2.4	0.9	-0.2	-1.0	4.2	7.1	3.3	2.9
0211:	37	2.4	0.7	-0.4	-1.4	1.9	5.5	2.6	1.1
0212:	37	2.4	1.1	-0.0	-0.9	4.4	7.3	3.5	3.0
0213:	38	2.5	0.8	-0.2	-1.3	2.1	5.6	2.7	1.1
0214:	38	2.5	1.2	0.2	-0.8	4.6	7.4	3.6	3.0
0215:	39	2.5	1.0	-0.1	-1.1	2.3	5.8	2.9	1.2
0216:	39	2.5	1.4	0.3	-0.6	4.8	7.6	3.8	3.1
0217:	40	2.6	1.2	0.1	-1.0	2.5	6.0	3.0	1.2
0218:	40	2.6	1.6	0.5	-0.5	5.0	7.8	3.9	3.1
0219:	-40	1.9	2.6	2.4	2.2	1.4	0.7	1.7	1.8
0220:	-40	1.9	3.0	2.8	2.7	3.9	2.5	2.6	3.7
0221:	-39	1.9	2.6	2.3	2.1	1.3	0.7	1.6	1.8
0222:	-39	1.9	3.0	2.7	2.6	3.8	2.5	2.5	3.7
0223:	-38	1.8	2.6	2.3	2.0	1.3	0.7	1.5	1.8
0224:	-38	1.8	3.0	2.7	2.5	3.8	2.5	2.4	3.7
0225:	-37	1.8	2.6	2.2	1.8	1.2	0.7	1.4	1.8
0226:	-37	1.8	3.0	2.6	2.3	3.7	2.5	2.3	3.6
0227:	-36	1.8	2.6	2.2	1.7	1.2	0.7	1.3	1.7
0228:	-36	1.8	3.0	2.6	2.2	3.7	2.5	2.2	3.6
0229:	-35	1.8	2.6	2.1	1.6	1.1	0.7	1.2	1.7
0230:	-35	1.8	3.0	2.5	2.1	3.6	2.5	2.1	3.6
0231:	-34	1.7	2.6	2.0	1.5	1.0	0.6	1.1	1.7
0232:	-34	1.7	3.0	2.4	2.0	3.5	2.4	2.0	3.6
0233:	-33	1.7	2.6	2.0	1.4	1.0	0.6	1.0	1.7
0234:	-33	1.7	3.0	2.4	1.9	3.5	2.4	1.9	3.5
0235:	-32	1.7	2.6	1.9	1.2	0.9	0.6	0.9	1.6
0236:	-32	1.7	3.0	2.3	1.7	3.4	2.4	1.8	3.5
0237:	-31	1.6	2.6	1.9	1.1	0.9	0.6	0.8	3.6
0238:	-31	1.6	3.0	2.3	1.6	3.4	2.4	1.7	3.5
0239:	-30	1.6	2.5	1.8	1.0	0.8	0.6	0.7	1.6
0240:	-30	1.6	2.9	2.2	1.5	3.3	2.4	1.6	3.5

0241:	-29	1.6	2.5	1.7	0.9	0.7	0.6	0.6	1.6
0242:	-29	1.6	2.9	2.1	1.4	3.2	2.4	1.5	3.4
0243:	-28	1.5	2.5	1.7	0.8	0.7	0.6	0.5	1.5
0244:	-28	1.5	2.9	2.1	1.3	3.2	2.4	1.4	3.4
0245:	-27	1.5	2.5	1.6	0.6	0.6	0.6	0.4	1.5
0246:	-27	1.5	2.9	2.0	1.1	3.1	2.4	1.3	3.4
0247:	-26	1.5	2.5	1.6	0.5	0.6	0.6	0.3	1.5
0248:	-26	1.5	2.9	2.0	1.0	3.1	2.4	1.2	3.4
0249:	-25	1.5	2.5	1.5	0.4	0.5	0.6	0.2	1.5
0250:	-25	1.5	2.9	1.9	0.9	3.0	2.4	1.1	3.3
0251:	-24	1.4	2.5	1.4	0.3	0.4	0.5	0.1	1.4
0252:	-24	1.4	2.9	1.8	0.8	2.9	2.3	1.0	3.3
0253:	-23	1.4	2.5	1.4	0.2	0.4	0.5	-0.0	1.4
0254:	-23	1.4	2.9	1.8	0.7	2.9	2.3	0.9	3.3
0255:	-22	1.4	2.5	1.3	0.0	0.3	0.5	-0.1	1.4
0256:	-22	1.4	2.9	1.7	0.5	2.8	2.3	0.8	3.3
0257:	-21	1.3	2.5	1.3	-0.1	0.3	0.5	-0.2	1.4
0258:	-21	1.3	2.9	1.7	0.4	2.8	2.3	0.7	3.2
0259:	-20	1.3	2.5	1.2	-0.2	0.2	0.5	-0.3	1.3
0260:	-20	1.3	2.9	1.6	0.3	2.7	2.3	0.6	3.2
0261:	-19	1.3	2.5	1.1	-0.4	0.1	0.4	-0.3	1.1
0262:	-19	1.3	2.9	1.5	0.1	2.6	2.2	0.6	3.0
0263:	-18	1.2	2.5	0.9	-0.7	.0	0.4	-0.4	1.0
0264:	-18	1.2	2.9	1.3	-0.2	2.5	2.2	0.5	2.9
0265:	-17	1.2	2.5	0.8	-0.9	-0.1	0.3	-0.4	0.8
0266:	-17	1.2	2.9	1.2	-0.4	2.4	2.1	0.5	2.7
0267:	-16	1.1	2.5	0.6	-1.1	-0.2	0.3	-0.5	0.7
0268:	-16	1.1	2.9	1.0	-0.6	2.3	2.1	0.4	2.6
0269:	-15	1.1	2.5	0.5	-1.4	-0.3	0.2	-0.5	0.5
0270:	-15	1.1	2.9	0.9	-0.9	2.2	2.0	0.4	2.4
0271:	-14	1.1	2.5	0.4	-1.6	-0.4	0.1	-0.5	0.3
0272:	-14	1.1	2.9	0.8	-1.1	2.1	1.9	0.4	2.2
0273:	-13	1.0	2.5	0.2	-1.8	-0.5	0.1	-0.6	0.2
0274:	-13	1.0	2.9	0.6	-1.3	2.0	1.9	0.3	2.1
0275:	-12	1.0	2.5	0.1	-2.0	-0.6	0.0	-0.6	0.0
0276:	-12	1.0	2.9	0.5	-1.5	1.9	1.8	0.3	1.9
0277:	-11	0.9	2.5	-0.1	-2.3	-0.7	0.0	-0.7	-0.1
0278:	-11	0.9	2.9	0.3	-1.8	1.8	1.8	0.2	1.8
0279:	-10	0.9	2.5	-0.2	-2.5	-0.8	-0.1	-0.7	-0.3
0280:	-10	0.9	2.9	0.2	-2.0	1.7	1.7	0.2	1.6
0281:	-9	0.8	2.5	-0.4	-2.6	-1.0	-0.1	-0.6	-0.4
0282:	-9	0.8	2.9	0.0	-2.1	1.5	1.7	0.3	1.5
0283:	-8	0.7	2.5	-0.5	-2.7	-1.2	-0.2	-0.5	-0.5
0284:	-8	0.7	2.9	-0.1	-2.2	1.3	1.6	0.4	1.4
0285:	-7	0.7	2.5	-0.7	-2.8	-1.4	-0.2	-0.5	-0.5
0286:	-7	0.7	2.9	-0.3	-2.3	1.1	1.6	0.4	1.4
0287:	-6	0.6	2.5	-0.8	-2.9	-1.6	-0.3	-0.4	-0.6
0288:	-6	0.6	2.9	-0.4	-2.4	0.9	1.5	0.5	1.3
0289:	-5	0.5	2.5	-1.0	-3.0	-1.8	-0.3	-0.3	-0.7
0290:	-5	0.5	2.9	-0.6	-2.5	0.7	1.5	0.6	1.2
0291:	-4	0.4	2.5	-1.2	-3.1	-2.0	-0.3	-0.2	-0.8
0292:	-4	0.4	2.9	-0.8	-2.6	0.5	1.5	0.7	1.1
0293:	-3	0.3	2.5	-1.3	-3.2	-2.2	-0.4	-0.1	-0.9
0294:	-3	0.3	2.9	-0.9	-2.7	0.3	1.4	0.8	1.0
0295:	-2	0.3	2.5	-1.5	-3.3	-2.4	-0.4	-0.1	-0.9
0296:	-2	0.3	2.9	-1.1	-2.8	0.1	1.4	0.8	1.0
0297:	-1	0.2	2.5	-1.6	-3.4	-2.6	-0.5	0.0	-1.0
0298:	-1	0.2	2.9	-1.2	-2.9	-0.1	1.3	0.9	0.9
0299:	0	0.1	2.5	-1.8	-3.5	-2.8	-0.5	0.1	-1.1
0300:	0	0.1	2.9	-1.4	-3.0	-0.3	1.3	1.0	0.8

0301:	1	0.2	2.5	-1.6	-3.4	-2.6	-0.5	0.0	-1.0
0302:	1	0.2	2.9	-1.2	-2.9	-0.1	1.3	0.9	0.9
0303:	2	0.3	2.5	-1.5	-3.3	-2.4	-0.4	-0.1	-0.9
0304:	2	0.3	2.9	-1.1	-2.8	0.1	1.4	0.8	1.0
0305:	3	0.3	2.5	-1.3	-3.2	-2.2	-0.4	-0.1	-0.9
0306:	3	0.3	2.9	-0.9	-2.7	0.3	1.4	0.8	1.0
0307:	4	0.4	2.5	-1.2	-3.1	-2.0	-0.3	-0.2	-0.8
0308:	4	0.4	2.9	-0.8	-2.6	0.5	1.5	0.7	1.1
0309:	5	0.5	2.5	-1.0	-3.0	-1.8	-0.3	-0.3	-0.7
0310:	5	0.5	2.9	-0.6	-2.5	0.7	1.5	0.6	1.2
0311:	6	0.6	2.5	-0.8	-2.9	-1.6	-0.3	-0.4	-0.6
0312:	6	0.6	2.9	-0.4	-2.4	0.9	1.5	0.5	1.3
0313:	7	0.7	2.5	-0.7	-2.8	-1.4	-0.2	-0.5	-0.5
0314:	7	0.7	2.9	-0.3	-2.3	1.1	1.6	0.4	1.4
0315:	8	0.7	2.5	-0.5	-2.7	-1.2	-0.2	-0.5	-0.5
0316:	8	0.7	2.9	-0.1	-2.2	1.3	1.6	0.4	1.4
0317:	9	0.8	2.5	-0.4	-2.6	-1.0	-0.1	-0.6	-0.4
0318:	9	0.8	2.9	0.0	-2.1	1.5	1.7	0.3	1.5
0319:	10	0.9	2.5	-0.2	-2.5	-0.8	-0.1	-0.7	-0.3
0320:	10	0.9	2.9	0.2	-2.0	1.7	1.7	0.2	1.6
0321:	11	0.9	2.5	-0.1	-2.3	-0.7	0.0	-0.7	-0.1
0322:	11	0.9	2.9	0.3	-1.8	1.8	1.8	0.2	1.8
0323:	12	1.0	2.5	0.1	-2.0	-0.6	0.0	-0.6	0.0
0324:	12	1.0	2.9	0.5	-1.5	1.9	1.8	0.3	1.9
0325:	13	1.0	2.5	0.2	-1.8	-0.5	0.1	-0.6	0.2
0326:	13	1.0	2.9	0.6	-1.3	2.0	1.9	0.3	2.1
0327:	14	1.1	2.5	0.4	-1.6	-0.4	0.1	-0.5	0.3
0328:	14	1.1	2.9	0.8	-1.1	2.1	1.9	0.4	2.2
0329:	15	1.1	2.5	0.5	-1.4	-0.3	0.2	-0.5	0.5
0330:	15	1.1	2.9	0.9	-0.9	2.2	2.0	0.4	2.4
0331:	16	1.1	2.5	0.6	-1.1	-0.2	0.3	-0.5	0.7
0332:	16	1.1	2.9	1.0	-0.6	2.3	2.1	0.4	2.6
0333:	17	1.2	2.5	0.8	-0.9	-0.1	0.3	-0.4	.8
0334:	17	1.2	2.9	1.2	-0.4	2.4	2.1	0.5	2.7
0335:	18	1.2	2.5	0.9	-0.7	.0	0.4	-0.4	1.0
0336:	18	1.2	2.9	1.3	-0.2	2.5	2.2	0.5	2.9
0337:	19	1.3	2.5	1.1	-0.4	0.1	0.4	-0.3	1.1
0338:	19	1.3	2.9	1.5	0.1	2.6	2.2	0.6	3.0
0339:	20	1.3	2.5	1.2	-0.2	0.2	0.5	-0.3	1.3
0340:	20	1.3	2.9	1.6	0.3	2.7	2.3	0.6	3.2
0341:	21	1.3	2.5	1.3	-0.1	0.3	0.5	-0.2	1.4
0342:	21	1.3	2.9	1.7	0.4	2.8	2.3	0.7	3.2
0343:	22	1.4	2.5	1.3	0.0	0.3	0.5	-0.1	1.4
0344:	22	1.4	2.9	1.7	0.5	2.8	2.3	0.8	3.3
0345:	23	1.4	2.5	1.4	0.2	0.4	0.5	-0.0	1.4
0346:	23	1.4	2.9	1.8	0.7	2.9	2.3	0.9	3.3
0347:	24	1.4	2.5	1.4	0.3	0.4	0.5	0.1	1.4
0348:	24	1.4	2.9	1.8	0.8	2.9	2.3	1.0	3.3
0349:	25	1.5	2.5	1.5	0.4	0.5	0.6	0.2	1.5
0350:	25	1.5	2.9	1.9	0.9	3.0	2.4	1.1	3.3
0351:	26	1.5	2.5	1.6	0.5	0.6	0.6	0.3	1.5
0352:	26	1.5	2.9	2.0	1.0	3.1	2.4	1.2	3.4
0353:	27	1.5	2.5	1.6	0.6	0.6	0.6	0.4	.5
0354:	27	1.5	2.9	2.0	1.1	3.1	2.4	1.3	3.4
0355:	28	1.5	2.5	1.7	0.8	0.7	0.6	0.5	.5
0356:	28	1.5	2.9	2.1	1.3	3.2	2.4	1.4	3.4
0357:	29	1.6	2.5	1.7	0.9	0.7	0.6	0.6	.6
0358:	29	1.6	2.9	2.1	1.4	3.2	2.4	1.5	3.4
0359:	30	1.6	2.5	1.8	1.0	0.8	0.6	0.7	1.6
0360:	30	1.6	2.9	2.2	1.5	3.3	2.4	1.6	3.5

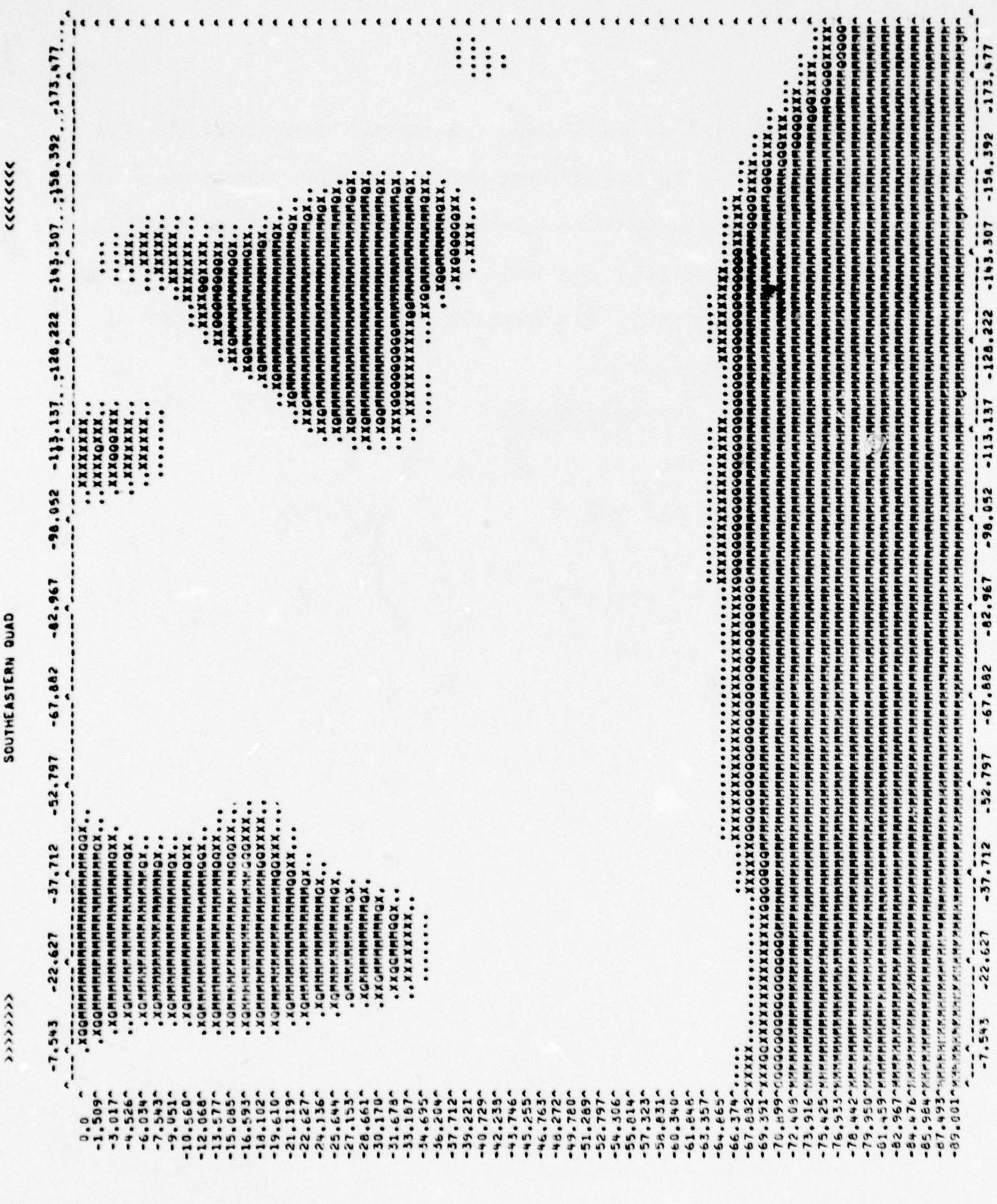
```
0361:      31  1.6  2.6  1.9  1.1  0.9  0.6  0.8  1.6
0362:      31  1.6  3.0  2.3  1.6  3.4  2.4  1.7  3.5
0363:      32  1.7  2.6  1.9  1.2  0.9  0.6  0.9  1.6
0364:      32  1.7  3.0  2.3  1.7  3.4  2.4  1.8  3.5
0365:      33  1.7  2.6  2.0  1.4  1.0  0.6  1.0  1.7
0366:      33  1.7  3.0  2.4  1.9  3.5  2.4  1.9  3.5
0367:      34  1.7  2.6  2.0  1.5  1.0  0.6  1.1  1.7
0368:      34  1.7  3.0  2.4  2.0  3.5  2.4  2.0  3.6
0369:      35  1.8  2.6  2.1  1.6  1.1  0.7  1.2  1.7
0370:      35  1.8  3.0  2.5  2.1  3.6  2.5  2.1  3.6
0371:      36  1.8  2.6  2.2  1.7  1.2  0.7  1.3  1.7
0372:      36  1.8  3.0  2.6  2.2  3.7  2.5  2.2  3.6
0373:      37  1.8  2.6  2.2  1.8  1.2  0.7  1.4  1.8
0374:      37  1.8  3.0  2.6  2.3  3.7  2.5  2.3  3.6
0375:      38  1.8  2.6  2.3  2.0  1.3  0.7  1.5  1.8
0376:      38  1.8  3.0  2.7  2.5  3.8  2.5  2.4  3.7
0377:      39  1.9  2.6  2.3  2.1  1.3  0.7  1.6  1.8
0378:      39  1.9  3.0  2.7  2.6  3.8  2.5  2.5  3.7
0379:      40  1.9  2.6  2.4  2.2  1.4  0.7  1.7  1.8
0380:      40  1.9  3.0  2.8  2.7  3.9  2.5  2.6  3.7
0381:  /*
0382:  //
```

APPENDIX A

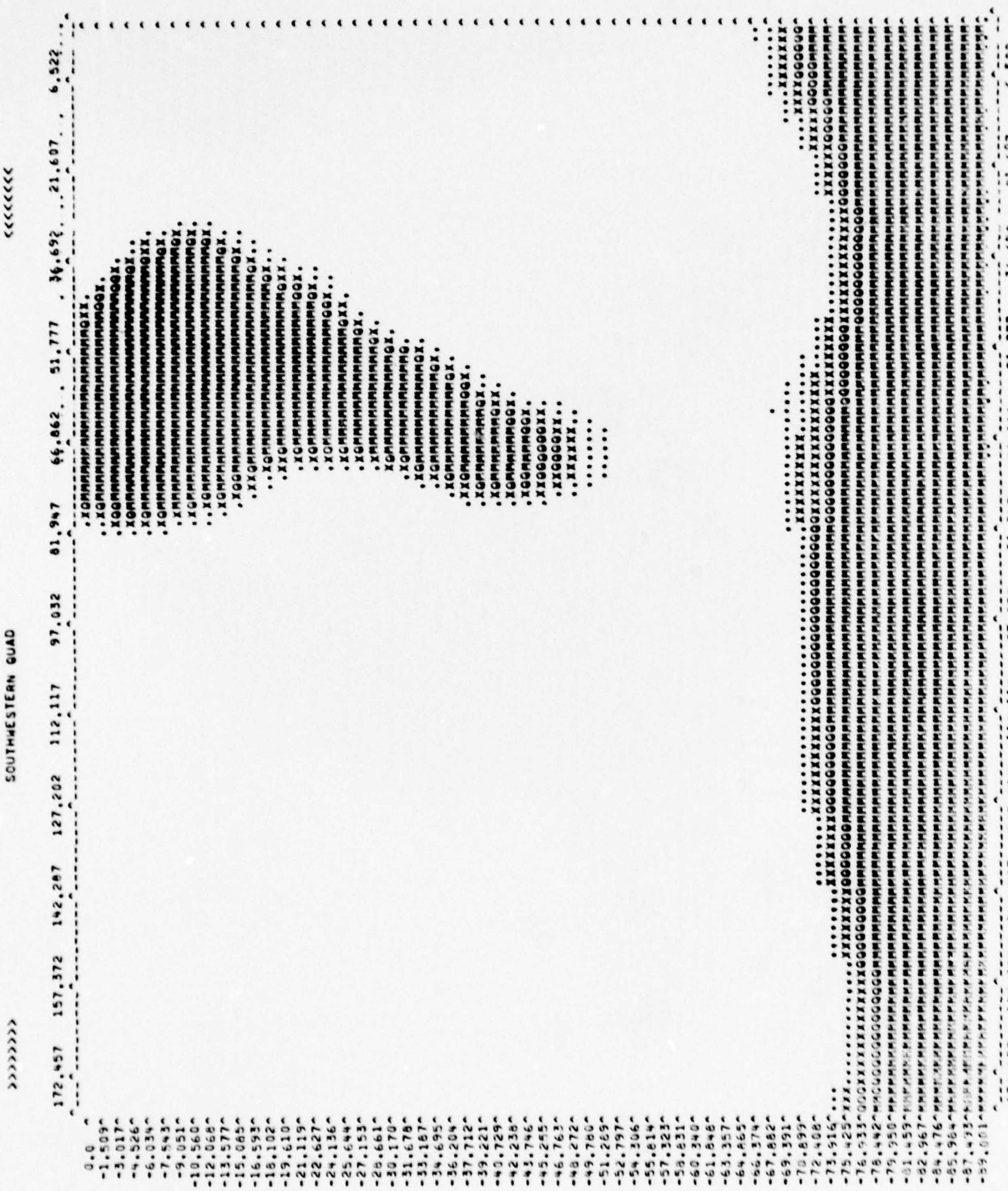
INVERSE MAPPING TRANSFORMATION FROM NWOMAP

The following four maps show the NWOMAP data from the ITS numerical world map in NUCOM/BREM and NUCOM II. These maps were obtained by calling NWOMAP for each point on a fine grid of latitude and longitude values and then applying the transformations in FSGEPS to each point. The symbols are defined in terms of conductivity as follows:

SYMBOL	σ RANGE, Mho/m
Blank	5.0
"."	3.75-5.0
"X"	2.5-3.75
"Q"	1.25-2.5
"M"	0-1.25


>>>>>>>> SOUTHEASTERN QUAD <<<<<<<<
-7.543 -22.627 -37.712 -52.797 -67.882 -82.967 -98.052 -113.137 -128.222 -143.307 -158.392 -173.477
0.0
-1.509
-3.017
-4.526
-6.034
-7.543
-9.051
-10.560
-12.068
-13.577
-15.085
-16.593
-18.102
-19.610
-21.119
-22.627
-24.136
-25.644
-27.153
-28.661
-30.170
-31.678
-33.187
-34.695
-36.204
-37.712
-39.221
-40.729
-42.238
-43.746
-45.255
-46.763
-48.272
-49.780
-51.289
-52.797
-54.306
-55.814
-57.323
-58.831
-60.340
-61.848
-63.357
-64.865
-66.374
-67.882
-69.391
-70.899
-72.408
-73.916
-75.425
-76.933
-78.442
-79.950
-81.459
-82.967
-84.476
-85.984
-87.493
-89.001


>>>>>>>> NORTHWESTERN QUAD <<<<<<<<
172.457 157.372 142.287 127.202 112.117 97.032 81.947 66.862 51.777 36.692 21.607 6.522


SOUTHWESTERN QUAD
>>>>>>>>
<<<<<<<<
172.457
157.372
142.287
127.202
112.117
97.032
81.947
66.862
51.777
36.692
21.607
6.522
0.0
-1.509
-3.017
-4.526
-6.034
-7.543
-9.051
-10.560
-12.068
-13.577
-15.085
-16.593
-18.102
-19.610
-21.119
-22.627
-24.136
-25.644
-27.153
-28.661
-30.170
-31.678
-33.187
-34.695
-36.204
-37.712
-39.221
-40.729
-42.238
-43.746
-45.255
-46.763
-48.272
-49.780
-51.289
-52.797
-54.306
-55.814
-57.323
-58.831
-60.340
-61.848
-63.357
-64.865
-66.374
-67.882
-69.391
-70.899
-72.408
-73.916
-75.425
-76.933
-78.442
-79.950
-81.459
-82.967
-84.476
-85.984
-87.493
-89.001


>>>>>>>> NORTHEASTERN QUAD <<<<<<<<
-7.542 -22.627 -37.712 -52.797 -67.882 -82.967 -98.052 -113.137 -128.222 -143.307 -158.392 -173.477

APPENDIX B

AIRBORNE ANTENNA PATTERNS

This section contains digitized airborne antenna pattern data in a format suitable for direct inclusion in NUCOM/BREM. This data has been digitized from the graphical information in Section 2.

The tail-to-fuselage wire data for the EC-135 has been extrapolated by the assumption that the pattern is symmetrical about the $\Theta = 90^{\circ}$ plane. Horizontal powers have been obtained by application of the results of Wong (op.cit.).

The notch antenna patterns have been reduced from the data in Figure 2-47 for a frequency of 2.0 MHz.

EC-135 tail-fuselage wire, frequencies, 2.0, 3.0, 4.0, 5.0, 7.0, 10.0, 15.0 MHz. Pattern in $\emptyset = 0^{\circ}$ plane.

```
2.0  3.0  4.0  5.0  7.0  10.0 15.0
-402.6001.200  0.1-1.00  2.5  6.0  3.0  1.2
-40  2.6  1.6  0.5 -0.5  5.0  7.8  3.9  3.1
-372.545 1.02 -0.1-1.13  2.3  5.8  2.9  1.2
-39  2.5  1.4  0.3 -0.6  4.8  7.6  3.8  3.1
-382.490 0.84 -0.2-1.26  2.1  5.6  2.7  1.1
-38  2.5  1.2  0.2 -0.8  4.6  7.4  3.6  3.0
-372.435 0.66 -0.4-1.39  1.9  5.5  2.6  1.1
-37  2.4  1.1 -0.0 -0.9  4.4  7.3  3.5  3.0
-362.380 0.48 -0.6-1.52  1.7  5.3  2.4  1.0
-36  2.4  0.9 -0.2 -1.0  4.2  7.1  3.3  2.9
-352.325 0.30 -0.7-1.65  1.5  5.1  2.3  1.0
-35  2.3  0.7 -0.3 -1.2  4.0  6.9  3.2  2.9
-342.270 0.12 -0.9-1.78  1.3  4.9  2.2  1.0
-34  2.3  0.5 -0.5 -1.3  3.8  6.7  3.1  2.9
-332.215-0.06 -1.1-1.91  1.1  4.7  2.0  1.9
-33  2.2  0.3 -0.7 -1.4  3.6  6.5  2.9  2.8
-322.160-0.24 -1.2-2.04  0.9  4.6  1.9  0.9
-32  2.2  0.2 -0.8 -1.5  3.4  6.4  2.8  2.8
-312.105-0.42 -1.4-2.17  0.7  4.4  1.7  0.8
-31  2.1  0.0 -1.0 -1.7  3.2  6.2  2.6  -.7
-302.050-0.60 -1.6-2.30  0.5  4.2  1.6  0.8
-30  2.1 -0.2 -1.2 -1.8  3.0  6.0  2.5  2.7
-291.995-0.78 -1.7-2.43  0.3  4.0  1.5  0.8
-29  2.0 -0.4 -1.3 -1.9  2.8  5.8  2.4  2.7
-281.940-0.96 -1.9-2.56  0.1  3.8  1.3  0.7
-28  1.9 -0.6 -1.6 -2.1  2.6  5.6  2.2  2.6
-271.885-1.14 -2.0-2.69 -0.1  3.7  1.2  0.7
-27  1.9 -0.7 -1.6 -2.2  2.4  5.5  2.1  2.6
-261.830-1.32 -2.2-2.82 -0.3  3.5  1.0  0.6
-26  1.8 -0.9 -1.8 -2.0  2.2  5.3  1.9  2.5
-251.775-1.50 -2.4-2.95 -0.5  3.3  0.9  0.6
-25  1.8 -1.1 -2.0 -2.5  2.0  5.1  1.8  2.5
-241.720-1.68 -2.5-3.08 -0.7  3.1  0.8  0.6
-24  1.7 -1.3 -2.1 -2.6  1.8  4.9  1.7  2.5
-231.665-1.86 -2.7-3.21 -0.9  2.9  0.6  0.5
-23  1.7 -1.5 -2.3 -2.7  1.6  4.7  1.5  2.4
-221.610-2.04 -2.9-3.34 -1.1  2.8  0.5  0.5
-22  1.6 -1.6 -2.5 -2.8  1.4  4.6  1.4  2.4
-211.555-2.22 -3.0-3.47 -1.3  2.6  0.3  0.4
-21  1.6 -1.8 -2.6 -3.0  1.2  4.4  1.2  2.3
-20 1.50-2.40 -3.2-3.60 -1.5  2.4  0.2  0.4
-20  1.5 -2.0 -2.8 -3.1  1.0  4.2  1.1  2.3
-19 1.45-2.71 -3.4-3.72 -1.7  2.2 -0.1  0.3
-19  1.5 -2.3 -3.0 -3.2  0.9  4.0  0.8  2.2
-18 1.40-3.02 -3.6-3.84 -1.8  1.9 -0.4  0.1
-18  1.4 -2.6 -3.2 -3.3  0.7  3.7  0.5  2.0
-17 1.35-3.33 -3.8-3.96 -2.0  1.7 -0.8  0.0
-17  1.4 -2.9 -3.4 -3.5  0.6  3.5  0.1  1.9
-16 1.30-3.64 -4.0-4.08 -2.1  1.4 -1.1 -0.2
-16  1.3 -3.2 -3.6 -3.6  0.4  3.2 -0.2  1.7
-15 1.25-3.95 -4.2-4.20 -2.3  1.2 -1.4 -0.3
-15  1.3 -3.6 -3.8 -3.7  0.3  3.0 -0.5  1.6
-14 1.20-4.26 -4.4-4.32 -2.4  1.0 -1.7 -0.4
-14  1.2 -3.9 -4.0 -3.8  0.1  2.8 -0.8  1.5
-13 1.15-4.57 -4.6-4.44 -2.6  0.7 -2.0 -0.6
-13  1.2 -4.2 -4.2 -3.9 -0.1  2.5 -1.1  1.3
-12 1.10-4.88 -4.8-4.56 -2.7  0.5 -2.4 -0.7
-12  1.1 -4.5 -4.4 -4.1 -0.2  2.3 -1.5  1.2
-11 1.05-5.19 -5.0-4.68 -2.9  0.2 -2.7 -0.9
```

0061:	-11	1.0	-4.8	-4.6	-4.2	-0.4	2.0	-1.8	.0
0062:	-10	1.0	-5.50	-5.20	-4.80	-3.0	0.0	-3.0	-1.0
0063:	-10	1.0	-5.1	-4.8	-4.3	-0.5	1.8	-2.1	0.9
0064:	-9	0.8	-6.0	-5.56	-4.80	-3.2	-0.4	-3.4	-1.2
0065:	-9	0.8	-5.6	-5.1	-4.3	-0.7	1.4	-2.5	0.7
0066:	-8	0.6	-6.5	-5.92	-4.80	-3.4	-0.8	-3.9	-1.5
0067:	-8	0.6	-6.1	-5.5	-4.3	-0.9	1.0	-3.0	0.4
0068:	-7	0.4	-7.0	-6.28	-4.80	-3.6	-1.2	-4.3	-1.7
0069:	-7	0.4	-6.6	-5.9	-4.3	-1.1	0.6	-3.4	0.2
0070:	-6	0.2	-7.5	-6.64	-4.80	-3.8	-1.6	-4.8	-2.0
0071:	-6	0.2	-7.1	-6.2	-4.3	-1.3	0.2	-3.9	-0.1
0072:	-5	0.0	-8.0	-7.00	-4.80	-4.0	-2.0	-5.2	-2.2
0073:	-5	0.0	-7.6	-6.6	-4.3	-1.5	-0.2	-4.3	-0.3
0074:	-4	-0.2	-8.5	-7.36	-4.80	-4.2	-2.4	-5.6	-2.4
0075:	-4	-0.2	-8.1	-7.0	-4.3	-1.7	-0.6	-4.7	-0.5
0076:	-3	-0.4	-9.0	-7.72	-4.80	-4.4	-2.8	-6.1	-2.7
0077:	-3	-0.4	-8.6	-7.3	-4.3	-1.9	-1.0	-5.2	-0.8
0078:	-2	-0.6	-9.5	-8.08	-4.80	-4.6	-3.2	-6.5	-2.9
0079:	-2	-0.6	-9.1	-7.6	-4.3	-2.1	-1.4	-5.6	-1.0
0080:	-1	-0.8	-10.0	-8.44	-4.80	-4.8	-3.6	-7.0	-3.2
0081:	-1	-0.8	-9.6	-8.0	-4.3	-2.3	-1.8	-6.1	-1.3
0082:	0	-1.0	-10.5	-8.8	-4.8	-5.0	-4.0	-7.4	-3.4
0083:	0	-1.0	-10.1	-8.4	-4.3	-2.5	-2.2	-6.5	-1.5
0084:	1	-0.8	-10.0	-8.4	-4.8	-4.8	-3.6	-7.0	-3.2
0085:	1	-0.8	-9.6	-8.0	-4.3	-2.3	-1.8	-6.1	-1.3
0086:	2	-0.6	-9.5	-8.1	-4.8	-4.6	-3.2	-6.5	-2.9
0087:	2	-0.6	-9.1	-7.6	-4.3	-2.1	-1.4	-5.6	-1.0
0088:	3	-0.4	-9.0	-7.7	-4.8	-4.4	-2.8	-6.1	-2.7
0089:	3	-0.4	-8.6	-7.3	-4.3	-1.9	-1.0	-5.2	-0.8
0090:	4	-0.2	-8.5	-7.4	-4.8	-4.2	-2.4	-5.6	-2.4
0091:	4	-0.2	-8.1	-7.0	-4.3	-1.7	-0.6	-4.7	-0.5
0092:	5	0.0	-8.0	-7.0	-4.8	-4.0	-2.0	-5.2	-2.2
0093:	5	0.0	-7.6	-6.6	-4.3	-1.5	-0.2	-4.3	-0.3
0094:	6	0.2	-7.5	-6.6	-4.8	-3.8	-1.6	-4.8	-2.0
0095:	6	0.2	-7.1	-6.2	-4.3	-1.3	0.2	-3.9	-0.1
0096:	7	0.4	-7.0	-6.3	-4.8	-3.6	-1.2	-4.3	-1.7
0097:	7	0.4	-6.6	-5.9	-4.3	-1.1	0.6	-3.4	0.2
0098:	8	0.6	-6.5	-5.9	-4.8	-3.4	-0.8	-3.9	-1.5
0099:	8	0.6	-6.1	-5.5	-4.3	-0.9	1.0	-3.0	.4
0100:	9	0.8	-6.0	-5.6	-4.8	-3.2	-0.4	-3.4	-1.2
0101:	9	0.8	-5.6	-5.1	-4.3	-0.7	1.4	-2.5	0.7
0102:	10	1.0	-5.5	-5.2	-4.8	-3.0	0.0	-3.0	-1.0
0103:	10	1.0	-5.1	-4.8	-4.3	-0.5	1.8	-2.1	0.9
0104:	11	1.0	-5.2	-5.0	-4.7	-2.9	0.2	-2.7	-0.9
0105:	11	1.0	-4.8	-4.6	-4.2	-0.4	2.0	-1.8	1.0
0106:	12	1.1	-4.9	-4.8	-4.6	-2.7	0.5	-2.4	-0.7
0107:	12	1.1	-4.5	-4.4	-4.1	-0.2	2.3	-1.5	1.2
0108:	13	1.2	-4.6	-4.6	-4.4	-2.6	0.7	-2.0	-0.6
0109:	13	1.2	-4.2	-4.2	-3.9	-0.1	2.5	-1.1	1.3
0110:	14	1.2	-4.3	-4.4	-4.3	-2.4	1.0	-1.7	-0.4
0111:	14	1.2	-3.9	-4.0	-3.8	0.1	2.8	-0.9	1.5
0112:	15	1.3	-4.0	-4.2	-4.2	-2.3	1.2	-1.4	-0.3
0113:	15	1.3	-3.6	-3.8	-3.7	0.3	3.0	-0.5	1.6
0114:	16	1.3	-3.6	-4.0	-4.1	-2.1	1.4	-1.1	-0.2
0115:	16	1.3	-3.2	-3.6	-3.6	0.4	3.2	-0.2	1.7
0116:	17	1.4	-3.3	-3.8	-4.0	-2.0	1.7	-0.8	0.0
0117:	17	1.4	-2.9	-3.4	-3.5	0.6	3.5	0.1	1.9
0118:	18	1.4	-3.0	-3.6	-3.8	-1.8	1.9	-0.4	0.1
0119:	18	1.4	-2.6	-3.2	-3.3	0.7	3.7	0.5	.0
0120:	19	1.5	-2.7	-3.4	-3.7	-1.7	2.2	-0.1	0.3

0121:	19	1.5	-2.5	-3.0	-3.2	0.9	4.0	0.9	2.2
0122:	20	1.5	-2.4	-3.2	-3.6	-1.5	2.4	0.2	0.4
0123:	20	1.5	-2.0	-2.8	-3.1	1.0	4.2	1.1	2.3
0124:	21	1.6	-2.2	-3.0	-3.5	-1.3	2.6	0.3	0.4
0125:	21	1.6	-1.8	-2.6	-3.0	1.2	4.4	1.2	2.3
0126:	22	1.6	-2.0	-2.9	-3.3	-1.1	2.8	0.5	0.5
0127:	22	1.6	-1.6	-2.5	-2.8	1.4	4.6	1.4	2.4
0128:	23	1.7	-1.9	-2.7	-3.2	-0.9	2.9	0.6	0.5
0129:	23	1.7	-1.5	-2.3	-2.7	1.6	4.7	1.5	2.4
0130:	24	1.7	-1.7	-2.5	-3.1	-0.7	3.1	0.8	0.6
0131:	24	1.7	-1.3	-2.1	-2.6	1.8	4.9	1.7	2.5
0132:	25	1.8	-1.5	-2.4	-3.0	-0.5	3.3	0.9	0.6
0133:	25	1.8	-1.1	-2.0	-2.5	2.0	5.1	1.8	2.5
0134:	2[illegible]	1.8	-1.3	-2.2	-2.9	-0.3	3.5	1.0	0.6
0135:	26	1.8	-0.9	-1.8	-2.0	2.2	5.3	1.9	2.5
0136:	27	1.9	-1.1	-2.0	-2.7	-0.1	3.7	1.2	0.7
0137:	27	1.9	-0.7	-1.6	-2.2	2.4	5.5	2.1	2.6
0138:	28	1.9	-1.0	-1.9	-2.6	0.1	3.8	1.3	0.7
0139:	28	1.9	-0.6	-1.6	-2.1	2.6	5.6	2.2	2.6
0140:	29	2.0	-0.8	-1.7	-2.4	0.3	4.0	1.5	0.8
0141:	29	2.0	-0.4	-1.3	-1.9	2.8	5.9	2.4	2.7
0142:	30	2.1	-0.6	-1.6	-2.3	0.5	4.2	1.6	0.8
0143:	30	2.1	-0.2	-1.2	-1.8	3.0	6.0	2.5	2.7
0144:	31	2.1	-0.4	-1.4	-2.2	0.7	4.4	1.7	0.8
0145:	31	2.1	0.0	-1.0	-1.7	3.2	6.2	2.6	2.7
0146:	32	2.2	-0.2	-1.2	-2.0	0.9	4.6	1.9	0.9
0147:	32	2.2	0.2	-0.8	-1.5	3.4	6.4	2.8	2.8
0148:	33	2.2	-0.1	-1.1	-1.9	1.1	4.7	2.0	0.9
0149:	33	2.2	0.3	-0.7	-1.4	3.6	6.5	2.9	2.8
0150:	34	2.3	0.1	-0.9	-1.8	1.3	4.9	2.2	1.0
0151:	34	2.3	0.5	-0.5	-1.3	3.8	6.7	3.1	2.9
0152:	35	2.3	0.3	-0.7	-1.7	1.5	5.1	2.3	1.0
0153:	35	2.3	0.7	-0.3	-1.2	4.0	6.9	3.2	2.9
0154:	36	2.4	0.5	-0.6	-1.5	1.7	5.3	2.4	1.0
0155:	36	2.4	0.9	-0.2	-1.0	4.2	7.1	3.3	2.9
0156:	37	2.4	0.7	-0.4	-1.4	1.9	5.5	2.6	1.1
0157:	37	2.4	1.1	-0.0	-0.9	4.4	7.3	3.5	3.0
0158:	38	2.5	0.8	-0.2	-1.3	2.1	5.6	2.7	1.1
0159:	38	2.5	1.2	0.2	-0.8	4.6	7.4	3.6	3.0
0160:	39	2.5	1.0	-0.1	-1.1	2.3	5.8	2.9	1.2
0161:	39	2.5	1.4	0.3	-0.6	4.8	7.6	3.8	3.1
0162:	40	2.6	1.2	0.1	-1.0	2.5	6.0	3.0	.2
0163:	40	2.6	1.6	0.5	-0.5	5.0	7.8	3.9	3.1

EC-135 tail-fuselage wire, frequencies 2.0, 3.0, 4.0, 5.0, 7.0, 10.0, 15.0 MHz. Pattern in $\phi = 180^{\circ}$ plane.

0001:	2.0	3.0	4.0	5.0	7.0	10.0	15.0		
0002:	-40	1.9	2.6	2.4	2.2	1.4	0.7	1.7	1.8
0003:	-40	1.9	3.0	2.8	2.7	3.9	2.5	2.6	3.7
0004:	-39	1.9	2.6	2.3	2.1	1.3	0.7	1.6	1.8
0005:	-39	1.9	3.0	2.7	2.6	3.8	2.5	2.5	3.7
0006:	-38	1.8	2.6	2.3	2.0	1.3	0.7	1.5	1.8
0007:	-38	1.8	3.0	2.7	2.5	3.8	2.5	2.4	3.7
0008:	-37	1.8	2.6	2.2	1.8	1.2	0.7	1.4	1.8
0009:	-37	1.8	3.0	2.6	2.3	3.7	2.5	2.3	3.6
0010:	-36	1.8	2.6	2.2	1.7	1.2	0.7	1.3	1.7
0011:	-36	1.8	3.0	2.6	2.2	3.7	2.5	2.2	3.6
0012:	-35	1.8	2.6	2.1	1.6	1.1	0.7	1.2	1.7
0013:	-35	1.8	3.0	2.5	2.1	3.6	2.5	2.1	3.6
0014:	-34	1.7	2.6	2.0	1.5	1.0	0.6	1.1	1.7
0015:	-34	1.7	3.0	2.4	2.0	3.5	2.4	2.0	3.6
0016:	-33	1.7	2.6	2.0	1.4	1.0	0.6	1.0	1.7
0017:	-33	1.7	3.0	2.4	1.9	3.5	2.4	1.9	.5
0018:	-32	1.7	2.6	1.9	1.2	0.9	0.6	0.9	1.6
0019:	-32	1.7	3.0	2.3	1.7	3.4	2.4	1.8	3.5
0020:	-31	1.6	2.6	1.9	1.1	0.9	0.6	0.8	1.6
0021:	-31	1.6	3.0	2.3	1.6	3.4	2.4	1.7	3.5
0022:	-30	1.6	2.5	1.8	1.0	0.8	0.6	0.7	1.6
0023:	-30	1.6	2.9	2.2	1.5	3.3	2.4	1.6	3.5
0024:	-29	1.6	2.5	1.7	0.9	0.7	0.6	0.6	1.6
0025:	-29	1.6	2.9	2.1	1.4	3.2	2.4	1.5	3.4
0026:	-28	1.5	2.5	1.7	0.8	0.7	0.6	0.5	1.5
0027:	-28	1.5	2.9	2.1	1.3	3.2	2.4	1.4	3.4
0028:	-27	1.5	2.5	1.6	0.6	0.6	0.6	0.4	1.5
0029:	-27	1.5	2.9	2.0	1.1	3.1	2.4	1.3	.4
0030:	-26	1.5	2.5	1.6	0.5	0.6	0.6	0.3	1.5
0031:	-26	1.5	2.9	2.0	1.0	3.1	2.4	1.2	3.4
0032:	-25	1.5	2.5	1.5	0.4	0.5	0.6	0.2	1.5
0033:	-25	1.5	2.9	1.9	0.9	3.0	2.4	1.1	3.3
0034:	-24	1.4	2.5	1.4	0.3	0.4	0.5	0.1	1.4
0035:	-24	1.4	2.9	1.8	0.8	2.9	2.3	1.0	3.3
0036:	-23	1.4	2.5	1.4	0.2	0.4	0.5	-0.0	1.4
0037:	-23	1.4	2.9	1.8	0.7	2.9	2.3	0.9	3.3
0038:	-22	1.4	2.5	1.3	0.0	0.3	0.5	-0.1	1.4
0039:	-22	1.4	2.9	1.7	0.5	2.8	2.3	0.8	3.3
0040:	-21	1.3	2.5	1.3	-0.1	0.3	0.5	-0.2	1.4
0041:	-21	1.3	2.9	1.7	0.4	2.8	2.3	0.7	3.2
0042:	-20	1.3	2.5	1.2	-0.2	0.2	0.5	-0.3	1.3
0043:	-20	1.3	2.9	1.6	0.3	2.7	2.3	0.6	3.2
0044:	-19	1.3	2.5	1.1	-0.4	0.1	0.4	-0.3	1.1
0045:	-19	1.3	2.9	1.5	0.1	2.6	2.2	0.6	3.0
0046:	-18	1.2	2.5	0.9	-0.7	.0	0.4	-0.4	1.0
0047:	-18	1.2	2.9	1.3	-0.2	2.5	2.2	0.5	2.9
0048:	-17	1.2	2.5	0.8	-0.9	-0.1	0.3	-0.4	0.8
0049:	-17	1.2	2.9	1.2	-0.4	2.4	2.1	0.5	2.7
0050:	-16	1.1	2.5	0.6	-1.1	-0.2	0.3	-0.5	0.7
0051:	-16	1.1	2.9	1.0	-0.6	2.3	2.1	0.4	2.6
0052:	-15	1.1	2.5	0.5	-1.4	-0.3	0.2	-0.5	0.5
0053:	-15	1.1	2.9	0.9	-0.9	2.2	2.0	0.4	2.4
0054:	-14	1.1	2.5	0.4	-1.6	-0.4	0.1	-0.5	0.3
0055:	-14	1.1	2.9	0.8	-1.1	2.1	1.9	0.4	.2
0056:	-13	1.0	2.5	0.2	-1.8	-0.5	0.1	-0.6	0.2
0057:	-13	1.0	2.9	0.6	-1.3	2.0	1.9	0.3	2.1
0058:	-12	1.0	2.5	0.1	-2.0	-0.6	0.0	-0.6	0.0
0059:	-12	1.0	2.9	0.5	-1.5	1.9	1.8	0.3	1.9
0060:	-11	0.9	2.5	-0.1	-2.3	-0.7	0.0	-0.7	-0.1

0061:	-11	0.9	2.9	0.3	-1.8	1.8	1.8	0.2	1.8
0062:	-10	0.9	2.5	-0.2	-2.5	-0.8	-0.1	-0.7	-0.3
0063:	-10	0.9	2.9	0.2	-2.0	1.7	1.7	0.2	1.6
0064:	-9	0.8	2.5	-0.4	-2.6	-1.0	-0.1	-0.6	-0.4
0065:	-9	0.8	2.9	0.0	-2.1	1.5	1.7	0.3	1.5
0066:	-8	0.7	2.5	-0.5	-2.7	-1.2	-0.2	-0.5	-0.5
0067:	-8	0.7	2.9	-0.1	-2.2	1.3	1.6	0.4	1.4
0068:	-7	0.7	2.5	-0.7	-2.8	-1.4	-0.2	-0.5	-0.5
0069:	-7	0.7	2.9	-0.3	-2.3	1.1	1.6	0.4	1.4
0070:	-6	0.6	2.5	-0.8	-2.9	-1.6	-0.3	-0.4	-0.6
0071:	-6	0.6	2.9	-0.4	-2.4	0.9	1.5	0.5	1.3
0072:	-5	0.5	2.5	-1.0	-3.0	-1.8	-0.3	-0.3	-0.7
0073:	-5	0.5	2.9	-0.6	-2.5	0.7	1.5	0.6	1.2
0074:	-4	0.4	2.5	-1.2	-3.1	-2.0	-0.3	-0.2	-0.8
0075:	-4	0.4	2.9	-0.8	-2.6	0.5	1.5	0.7	1.1
0076:	-3	0.3	2.5	-1.3	-3.2	-2.2	-0.4	-0.1	-0.9
0077:	-3	0.3	2.9	-0.9	-2.7	0.3	1.4	0.8	1.0
0078:	-2	0.3	2.5	-1.5	-3.3	-2.4	-0.4	-0.1	-0.9
0079:	-2	0.3	2.9	-1.1	-2.8	0.1	1.4	0.8	1.0
0080:	-1	0.2	2.5	-1.6	-3.4	-2.6	-0.5	0.0	-1.0
0081:	-1	0.2	2.9	-1.2	-2.9	-0.1	1.3	0.9	0.9
0082:	0	0.1	2.5	-1.8	-3.5	-2.8	-0.5	0.1	-1.1
0083:	0	0.1	2.9	-1.4	-3.0	-0.3	1.3	1.0	0.8
0084:	1	0.2	2.5	-1.6	-3.4	-2.6	-0.5	0.0	-1.0
0085:	1	0.2	2.9	-1.2	-2.9	-0.1	1.3	0.9	0.9
0086:	2	0.3	2.5	-1.5	-3.3	-2.4	-0.4	-0.1	-0.9
0087:	2	0.3	2.9	-1.1	-2.8	0.1	1.4	0.8	1.0
0088:	3	0.3	2.5	-1.3	-3.2	-2.2	-0.4	-0.1	-0.9
0089:	3	0.3	2.9	-0.9	-2.7	0.3	1.4	0.8	1.0
0090:	4	0.4	2.5	-1.2	-3.1	-2.0	-0.3	-0.2	-0.8
0091:	4	0.4	2.9	-0.8	-2.6	0.5	1.5	0.7	1.1
0092:	5	0.5	2.5	-1.0	-3.0	-1.8	-0.3	-0.3	-0.7
0093:	5	0.5	2.9	-0.6	-2.5	0.7	1.5	0.6	1.2
0094:	6	0.6	2.5	-0.8	-2.9	-1.6	-0.3	-0.4	-0.6
0095:	6	0.6	2.9	-0.4	-2.4	0.9	1.5	0.5	1.3
0096:	7	0.7	2.5	-0.7	-2.8	-1.4	-0.2	-0.5	-0.5
0097:	7	0.7	2.9	-0.3	-2.3	1.1	1.6	0.4	1.4
0098:	8	0.7	2.5	-0.5	-2.7	-1.2	-0.2	-0.5	-0.5
0099:	8	0.7	2.9	-0.1	-2.2	1.3	1.6	0.4	1.4
0100:	9	0.8	2.5	-0.4	-2.6	-1.0	-0.1	-0.6	-0.4
0101:	9	0.8	2.9	0.0	-2.1	1.5	1.7	0.3	1.5
0102:	10	0.9	2.5	-0.2	-2.5	-0.8	-0.1	-0.7	-0.3
0103:	10	0.9	2.9	0.2	-2.0	1.7	1.7	0.2	1.6
0104:	11	0.9	2.5	-0.1	-2.3	-0.7	0.0	-0.7	-0.1
0105:	11	0.9	2.9	0.3	-1.8	1.8	1.8	0.2	1.8
0106:	12	1.0	2.5	0.1	-2.0	-0.6	0.0	-0.6	0.0
0107:	12	1.0	2.9	0.5	-1.5	1.9	1.8	0.3	1.9
0108:	13	1.0	2.5	0.2	-1.8	-0.5	0.1	-0.6	0.2
0109:	13	1.0	2.9	0.6	-1.3	2.0	1.9	0.3	2.1
0110:	14	1.1	2.5	0.4	-1.6	-0.4	0.1	-0.5	0.3
0111:	14	1.1	2.9	0.8	-1.1	2.1	1.9	0.4	2.2
0112:	15	1.1	2.5	0.5	-1.4	-0.3	0.2	-0.5	0.5
0113:	15	1.1	2.9	0.9	-0.9	2.2	2.0	0.4	2.4
0114:	16	1.1	2.5	0.6	-1.1	-0.2	0.3	-0.5	0.7
0115:	16	1.1	2.9	1.0	-0.6	2.3	2.1	0.4	2.6
0116:	17	1.2	2.5	0.8	-0.9	-0.1	0.3	-0.4	0.8
0117:	17	1.2	2.9	1.2	-0.4	2.4	2.1	0.5	2.7
0118:	18	1.2	2.5	0.9	-0.7	.0	0.4	-0.4	[illegible]
0119:	18	1.2	2.9	1.3	-0.2	2.5	2.2	0.5	2.9
0120:	19	1.3	2.5	1.1	-0.4	0.1	0.4	-0.3	1.1

0121:	19	1.3	2.4	1.5	0.1	2.6	2.2	0.6	3.0
0122:	20	1.3	2.5	1.2	-0.2	0.2	0.5	-0.3	1.3
0123:	20	1.3	2.4	1.6	0.3	2.7	2.3	0.6	3.2
0124:	21	1.3	2.5	1.3	-0.1	0.3	0.5	-0.2	1.4
0125:	21	1.3	2.4	1.7	0.4	2.8	2.3	0.7	3.2
0126:	22	1.4	2.5	1.3	0.0	0.3	0.5	-0.1	1.4
0127:	22	1.4	2.4	1.7	0.5	2.8	2.3	0.8	3.3
0128:	23	1.4	2.5	1.4	0.2	0.4	0.5	-0.0	1.4
0129:	23	1.4	2.4	1.8	0.7	2.9	2.3	0.9	3.3
0130:	24	1.4	2.5	1.4	0.3	0.4	0.5	0.1	1.4
0131:	24	1.4	2.4	1.8	0.8	2.9	2.3	1.0	3.3
0132:	25	1.5	2.5	1.5	0.4	0.5	0.6	0.2	1.5
0133:	25	1.5	2.4	1.9	0.9	3.0	2.4	1.1	3.3
0134:	26	1.5	2.5	1.6	0.5	0.6	0.6	0.3	1.5
0135:	26	1.5	2.4	2.0	1.0	3.1	2.4	1.2	3.4
0136:	27	1.5	2.5	1.6	0.6	0.6	0.6	0.4	.5
0137:	27	1.5	2.4	2.0	1.1	3.1	2.4	1.3	3.4
0138:	28	1.5	2.5	1.7	0.8	0.7	0.6	0.5	1.5
0139:	28	1.5	2.4	2.1	1.3	3.2	2.4	1.4	3.4
0140:	29	1.6	2.5	1.7	0.9	0.7	0.6	0.6	.6
0141:	29	1.6	2.4	2.1	1.4	3.2	2.4	1.5	3.4
0142:	30	1.6	2.5	1.8	1.0	0.8	0.6	0.7	1.6
0143:	30	1.6	2.4	2.2	1.5	3.3	2.4	1.6	3.5
0144:	31	1.6	2.6	1.9	1.1	0.9	0.6	0.8	1.6
0145:	31	1.6	3.0	2.3	1.6	3.4	2.4	1.7	3.5
0146:	32	1.7	2.6	1.9	1.2	0.9	0.6	0.9	1.6
0147:	32	1.7	3.0	2.3	1.7	3.4	2.4	1.8	3.5
0148:	33	1.7	2.6	2.0	1.4	1.0	0.6	1.0	1.7
0149:	33	1.7	3.0	2.4	1.9	3.5	2.4	1.9	3.5
0150:	34	1.7	2.6	2.0	1.5	1.0	0.6	1.1	1.7
0151:	34	1.7	3.0	2.4	2.0	3.5	2.4	2.0	3.6
0152:	35	1.8	2.6	2.1	1.6	1.1	0.7	1.2	1.7
0153:	35	1.8	3.0	2.5	2.1	3.6	2.5	2.1	3.6
0154:	36	1.8	2.6	2.2	1.7	1.2	0.7	1.3	1.7
0155:	36	1.8	3.0	2.6	2.2	3.7	2.5	2.2	3.6
0156:	37	1.8	2.6	2.2	1.8	1.2	0.7	1.4	1.8
0157:	37	1.8	3.0	2.6	2.3	3.7	2.5	2.3	3.6
0158:	38	1.8	2.6	2.3	2.0	1.3	0.7	1.5	1.8
0159:	38	1.8	3.0	2.7	2.5	3.8	2.5	2.4	3.7
0160:	39	1.9	2.6	2.3	2.1	1.3	0.7	1.6	1.8
0161:	39	1.9	3.0	2.7	2.6	3.8	2.5	2.5	3.7
0162:	40	1.9	2.6	2.4	2.2	1.4	0.7	1.7	1.8
0163:	40	1.9	3.0	2.8	2.7	3.9	2.5	2.6	3.7

EC-135 tail-fuselage wire, frequencies 2.0, 3.0, 4.0, 5.0, 7.0, 10.0, 15.0 MHz. Pattern in $\phi = 90^{\circ}$ plane (both sides averaged).

```
0001:     2.0  3.0  4.0  5.0  7.0  10.0 15.0
0002:     -40 -4.0 -4.5 -3.4 -2.5 -3.3 -4.5 -0.7   .3
0003:     -40 -4.0 -4.1 -3.0 -2.0 -0.8 -2.7  0.2  3.2
0004:     -39 -4.3 -5.0 -3.8 -2.8 -3.4 -4.4 -1.0  1.0
0005:     -39 -4.3 -4.6 -3.4 -2.3 -0.9 -2.6 -0.1  2.9
0006:     -38 -4.5 -5.4 -4.1 -3.1 -3.6 -4.4 -1.3  0.6
0007:     -38 -4.5 -5.0 -3.7 -2.6 -1.1 -2.6 -0.4  2.5
0008:     -37 -4.8 -5.9 -4.5 -3.3 -3.7 -4.3 -1.6  0.3
0009:     -37 -4.8 -5.5 -4.1 -2.8 -1.2 -2.5 -0.7  2.2
0010:     -36 -5.0 -6.3 -4.8 -3.6 -3.9 -4.2 -2.0 -0.1
0011:     -36 -5.0 -5.9 -4.4 -3.1 -1.4 -2.4 -1.1  1.8
0012:     -35 -5.3 -6.8 -5.2 -3.9 -4.0 -4.2 -2.3 -0.4
0013:     -35 -5.3 -6.4 -4.8 -3.4 -1.5 -2.4 -1.4   .5
0014:     -34 -5.5 -7.2 -5.5 -4.2 -4.2 -4.1 -2.6 -0.7
0015:     -34 -5.5 -6.8 -5.1 -3.7 -1.7 -2.3 -1.7  1.2
0016:     -33 -5.8 -7.7 -5.9 -4.4 -4.3 -4.0 -2.9 -1.1
0017:     -33 -5.8 -7.3 -5.5 -3.9 -1.8 -2.2 -2.0  0.8
0018:     -32 -6.0 -8.1 -6.2 -4.7 -4.5 -4.0 -3.2 -1.4
0019:     -32 -6.0 -7.7 -5.8 -4.2 -2.0 -2.2 -2.3  0.5
0020:     -31 -6.3 -8.6 -6.6 -5.0 -4.6 -3.9 -3.5 -1.8
0021:     -31 -6.3 -8.2 -6.2 -4.5 -2.1 -2.1 -2.6  0.1
0022:     -30 -6.5 -9.0 -7.0 -5.3 -4.8 -3.9 -3.9 -2.1
0023:     -30 -6.5 -8.6 -6.6 -4.8 -2.3 -2.1 -3.0 -0.2
0024:     -29 -6.8 -9.5 -7.3 -5.5 -4.9 -3.8 -4.2 - .4
0025:     -29 -6.8 -9.1 -6.9 -5.0 -2.4 -2.0 -3.3 -0.5
0026:     -28 -7.0 -9.9 -7.7 -5.8 -5.0 -3.7 -4.5 -2.8
0027:     -28 -7.0 -9.5 -7.3 -5.3 -2.5 -1.9 -3.6 -0.9
0028:     -27 -7.3-10.4 -8.0 -6.1 -5.2 -3.7 -4.8 -3.1
0029:     -27 -7.3-10.0 -7.6 -5.6 -2.7 -1.9 -3.9 -1.2
0030:     -26 -7.5-10.8 -8.4 -6.4 -5.3 -3.6 -5.1 -3.5
0031:     -26 -7.5-10.4 -8.0 -5.9 -2.8 -1.8 -4.2 -1.6
0032:     -25 -7.8-11.3 -8.7 -6.6 -5.5 -3.5 -5.4 -3.8
0033:     -25 -7.8-10.9 -8.3 -6.1 -3.0 -1.7 -4.5 -1.9
0034:     -24 -8.0-11.7 -9.1 -6.9 -5.6 -3.5 -5.7 -4.1
0035:     -24 -8.0-11.3 -8.7 -6.4 -3.1 -1.7 -4.8 -2.2
0036:     -23 -8.3-12.2 -9.4 -7.2 -5.8 -3.4 -6.1 -4.5
0037:     -23 -8.3-11.8 -9.0 -6.7 -3.3 -1.6 -5.2 -2.6
0038:     -22 -8.5-12.6 -9.8 -7.5 -5.9 -3.3 -6.4 -4.8
0039:     -22 -8.5-12.2 -9.4 -7.0 -3.4 -1.5 -5.5 -2.9
0040:     -21 -8.8-13.1-10.1 -7.7 -6.1 -3.3 -6.7 -5.2
0041:     -21 -8.8-12.7 -9.7 -7.2 -3.6 -1.5 -5.8 -3.3
0042:     -20 -9.0-13.5-10.5 -8.0 -6.2 -3.2 -7.0 - .5
0043:     -20 -9.0-13.1-10.1 -7.5 -3.7 -1.4 -6.1 -3.6
0044:     -19 -9.4-13.4-10.6 -8.1 -6.2 -3.3 -7.5 -5.9
0045:     -19 -9.4-13.0-10.2 -7.6 -3.7 -1.5 -6.6 -4.0
0046:     -18 -9.7-13.3-10.6 -8.2 -6.2 -3.4 -8.0 -6.2
0047:     -18 -9.7-12.9-10.2 -7.7 -3.7 -1.6 -7.1 -4.3
0048:     -17-10.1-13.1-10.7 -8.3 -6.1 -3.4 -8.4 -6.6
0049:     -17-10.1-12.7-10.3 -7.8 -3.6 -1.6 -7.5 - .7
0050:     -16-10.4-13.0-10.7 -8.4 -6.1 -3.5 -8.9 -6.9
0051:     -1 -10.4-12.6-10.3 -7.9 -3.6 -1.7 -8.0 - .0
0052:     -15-10.8-12.9-10.8 -8.5 -6.1 -3.6 -9.4 -7.3
0053:     -15-10.8-12.5-10.4 -8.0 -3.6 -1.8 -8.5 -5.4
0054:     -14-11.1-12.8-10.8 -8.6 -6.1 -3.7 -9.9 -7.6
0055:     -14-11.1-12.4-10.4 -8.1 -3.6 -1.9 -9.0 -5.7
0056:     -13-11.5-12.7-10.9 -8.7 -6.1 -3.8-10.4 - .0
0057:     -13-11.5-12.3-10.5 -8.2 -3.6 -2.0 -9.5 -6.1
0058:     -12-11.8-12.5-10.9 -8.8 -6.0 -3.8-10.8 -8.3
0059:     -12-11.8-12.1-10.5 -8.3 -3.5 -2.0 -9.9 -6.4
0060:     -11-12.2-12.4-11.0 -8.9 -6.0 -3.9-11.3 -8.7
```

```
0061:     -11-12.2-12.0-10.6  -8.4  -3.5  -2.1-10.4  -6.8
0062:     -10-12.5-12.3-11.0  -9.0  -6.0  -4.0-11.8  -9.0
0063:     -10-12.5-11.9-10.6  -8.5  -3.5  -2.2-10.9  -7.1
0064:      -9-12.8-12.1-10.8  -9.0  -5.9  -4.0-12.2  -9.2
0065:      -9-12.8-11.7-10.4  -8.5  -3.4  -2.2-11.3  -7.3
0066:      -8-13.1-12.0-10.6  -9.0  -5.8  -4.0-12.7  -9.4
0067:      -8-13.1-11.6-10.2  -8.5  -3.3  -2.2-11.8  -7.5
0068:      -7-13.4-11.8-10.4  -9.0  -5.7  -4.0-13.1  -9.6
0069:      -7-13.4-11.4-10.0  -8.5  -3.2  -2.2-12.2  -7.7
0070:      -6-13.7-11.7-10.2  -9.0  -5.6  -4.0-13.6  -9.8
0071:      -6-13.7-11.3  -9.8  -8.5  -3.1  -2.2-12.7  -7.9
0072:      -5-14.0-11.5-10.0  -9.0  -5.5  -4.0-14.0-10.0
0073:      -5-14.0-11.1  -9.6  -8.5  -3.0  -2.2-13.1  -8.1
0074:      -4-14.3-11.3  -9.8  -9.0  -5.4  -4.0-14.4-10.2
0075:      -4-14.3-10.9  -9.4  -8.5  -2.9  -2.2-13.5  -8.3
0076:      -3-14.6-11.2  -9.6  -9.0  -5.3  -4.0-14.9-10.4
0077:      -3-14.6-10.8  -9.2  -8.5  -2.8  -2.2-14.0  -8.5
0078:      -2-14.9-11.0  -9.4  -9.0  -5.2  -4.0-15.3-10.6
0079:      -2-14.9-10.6  -9.0  -8.5  -2.7  -2.2-14.4  -8.7
0080:      -1-15.2-10.9  -9.2  -9.0  -5.1  -4.0-15.8-10.8
0081:      -1-15.2-10.5  -8.8  -8.5  -2.6  -2.2-14.9  -8.9
0082:       0-15.5-10.7  -9.0  -9.0  -5.0  -4.0-16.2-11.0
0083:       0-15.5-10.3  -8.6  -8.5  -2.5  -2.2-15.3  -  .1
0084:       1-15.2-10.9  -9.2  -9.0  -5.1  -4.0-15.8-10.8
0085:       1-15.2-10.5  -8.8  -8.5  -2.6  -2.2-14.9  -8.9
0086:       2-14.9-11.0  -9.4  -9.0  -5.2  -4.0-15.3-10.6
0087:       2-14.9-10.6  -9.0  -8.5  -2.7  -2.2-14.4  -8.7
0088:       3-14.6-11.2  -9.6  -9.0  -5.3  -4.0-14.9-10.4
0089:       3-14.6-10.8  -9.2  -8.5  -2.8  -2.2-14.0  -8.5
0090:       4-14.3-11.3  -9.8  -9.0  -5.4  -4.0-14.4-10.2
0091:       4-14.3-10.9  -9.4  -8.5  -2.9  -2.2-13.5  -8.3
0092:       5-14.0-11.5-10.0  -9.0  -5.5  -4.0-14.0-10.0
0093:       5-14.0-11.1  -9.6  -8.5  -3.0  -2.2-13.1  -8.1
0094:       6-13.7-11.7-10.2  -9.0  -5.6  -4.0-13.6  -9.8
0095:       6-13.7-11.3  -9.8  -8.5  -3.1  -2.2-12.7  -7.9
0096:       7-13.4-11.8-10.4  -9.0  -5.7  -4.0-13.1  -9.6
0097:       7-13.4-11.4-10.0  -8.5  -3.2  -2.2-12.2  -7.7
0098:       8-13.1-12.0-10.6  -9.0  -5.8  -4.0-12.7  -9.4
0099:       8-13.1-11.6-10.2  -8.5  -3.3  -2.2-11.8  -7.5
0100:       9-12.8-12.1-10.8  -9.0  -5.9  -4.0-12.2  -9.2
0101:       9-12.8-11.7-10.4  -8.5  -3.4  -2.2-11.3  -7.3
0102:      10-12.5-12.3-11.0  -9.0  -6.0  -4.0-11.8  -9.0
0103:      10-12.5-11.9-10.6  -8.5  -3.5  -2.2-10.9  -7.1
0104:      11-12.2-12.4-11.0  -8.9  -6.0  -3.9-11.3  -8.7
0105:      11-12.2-12.0-10.6  -8.4  -3.5  -2.1-10.4  -6.8
0106:      12-11.8-12.5-10.9  -8.8  -6.0  -3.8-10.8  -8.3
0107:      12-11.8-12.1-10.5  -8.3  -3.5  -2.0  -9.9  -6.4
0108:      13-11.5-12.7-10.9  -8.7  -6.1  -3.8-10.4  -9.0
0109:      13-11.5-12.3-10.5  -8.2  -3.6  -2.0  -9.5  -6.1
0110:      14-11.1-12.8-10.8  -8.6  -6.1  -3.7  -9.9  -  .6
0111:      14-11.1-12.4-10.4  -8.1  -3.6  -1.9  -9.0  -5.7
0112:      15-10.8-12.9-10.8  -8.5  -6.1  -3.6  -9.4  -[illegible].3
0113:      15-10.8-12.5-10.4  -8.0  -3.6  -1.8  -8.5  -5.4
0114:      16-10.4-13.0-10.7  -8.4  -6.1  -3.5  -8.9  -6.9
0115:      16-10.4-12.6-10.3  -7.9  -3.6  -1.7  -8.0  -5.0
0116:      17-10.1-13.1-10.7  -8.3  -6.1  -3.4  -8.4  -6.6
0117:      17-10.1-12.7-10.3  -7.8  -3.6  -1.6  -7.5  -4.7
0118:      18  -9.7-13.3-10.6  -8.2  -6.2  -3.4  -8.0  -6.2
0119:      19  -9.7-12.9-10.2  -7.7  -3.7  -1.6  -7.1  -4.3
0120:      19  -9.4-13.4-10.6  -8.1  -6.2  -3.3  -7.5  -5.9
```

0121:	19	-9.4	-13.0	-10.2	-7.6	-3.7	-1.5	-6.6	-[illegible].0
0122:	20	-9.4	-13.5	-10.5	-8.0	-6.2	-3.2	-7.0	-5.5
0123:	20	-9.0	-13.1	-10.1	-7.5	-3.7	-1.4	-6.1	-3.6
0124:	21	-9.2	-13.1	-10.1	-7.7	-6.1	-3.3	-6.7	-5.2
0125:	21	-9.4	-12.7	-9.7	-7.2	-3.6	-1.5	-5.8	-3.3
0126:	22	-8.5	-12.6	-9.8	-7.5	-5.9	-3.3	-6.4	-4.8
0127:	22	-8.5	-12.2	-9.4	-7.0	-3.4	-1.5	-5.5	-2.9
0128:	23	-9.3	-12.2	-9.4	-7.2	-5.8	-3.4	-6.1	-4.5
0129:	23	-9.3	-11.8	-9.0	-6.7	-3.3	-1.6	-5.2	-2.6
0130:	24	-8.0	-11.7	-9.1	-6.9	-5.6	-3.5	-5.7	-[illegible].1
0131:	24	-8.0	-11.5	-9.7	-6.4	-3.1	-1.7	-4.8	-2.2
0132:	25	-7.8	-11.3	-9.7	-6.6	-5.5	-3.5	-5.4	-3.8
0133:	25	-7.6	-10.9	-8.3	-6.1	-3.0	-1.7	-4.5	-1.9
0134:	26	-7.5	-10.8	-9.4	-6.4	-5.3	-3.6	-5.1	-3.5
0135:	26	-7.5	-10.4	-9.0	-5.9	-2.8	-1.8	-4.2	-1.6
0136:	27	-7.3	-10.4	-9.0	-6.1	-5.2	-3.7	-4.8	-3.1
0137:	27	-7.3	-10.0	-7.6	-5.6	-2.7	-1.9	-3.9	-1.2
0138:	28	-7.4	-9.9	-7.7	-5.8	-5.0	-3.7	-4.5	-2.8
0139:	28	-7.0	-9.5	-7.3	-5.3	-2.5	-1.9	-3.6	-0.9
0140:	29	-6.8	-9.5	-7.3	-5.5	-4.9	-3.8	-4.2	-2.4
0141:	29	-6.8	-9.1	-6.9	-5.0	-2.4	-2.0	-3.3	-0.5
0142:	30	-6.5	-9.0	-7.0	-5.3	-4.8	-3.9	-3.9	-2.1
0143:	30	-6.5	-8.6	-6.6	-4.8	-2.3	-2.1	-3.0	-0.2
0144:	31	-6.3	-8.6	-6.6	-5.0	-4.6	-3.9	-3.5	-1.8
0145:	31	-6.3	-8.2	-6.2	-4.5	-2.1	-2.1	-2.6	0.1
0146:	32	-6.0	-8.1	-6.2	-4.7	-4.5	-4.0	-3.2	-1.4
0147:	32	-6.0	-7.7	-5.8	-4.2	-2.0	-2.2	-2.3	0.5
0148:	33	-5.8	-7.7	-5.9	-4.4	-4.3	-4.0	-2.9	-1.1
0149:	33	-5.8	-7.3	-5.5	-3.9	-1.8	-2.2	-2.0	0.8
0150:	34	-5.5	-7.2	-5.5	-4.2	-4.2	-4.1	-2.6	-0.7
0151:	34	-5.5	-6.8	-5.1	-3.7	-1.7	-2.3	-1.7	1.2
0152:	35	-5.3	-6.8	-5.2	-3.9	-4.0	-4.2	-2.3	-0.4
0153:	35	-5.3	-6.4	-4.8	-3.4	-1.5	-2.4	-1.4	1.5
0154:	36	-5.0	-6.3	-4.8	-3.6	-3.9	-4.2	-2.0	-0.1
0155:	36	-5.0	-5.9	-4.4	-3.1	-1.4	-2.4	-1.1	1.8
0156:	37	-4.8	-5.9	-4.5	-3.3	-3.7	-4.3	-1.6	0.3
0157:	37	-4.8	-5.5	-4.1	-2.8	-1.2	-2.5	-0.7	2.2
0158:	38	-4.5	-5.4	-4.1	-3.1	-3.6	-4.4	-1.3	0.6
0159:	38	-4.5	-5.0	-3.7	-2.6	-1.1	-2.6	-0.4	2.5
0160:	39	-4.3	-5.0	-3.8	-2.9	-3.4	-4.4	-1.0	1.0
0161:	39	-4.3	-4.6	-3.4	-2.3	-0.9	-2.6	-0.1	2.9
0162:	40	-4.0	-4.5	-3.4	-2.5	-3.3	-4.5	-0.7	1.3
0163:	40	-4.0	-4.1	-3.0	-2.0	-0.8	-2.7	0.2	[illegible].2

Notch antenna, Douglas DC series airframe, pattern in $\phi = 0^{\circ}$ plane. Frequency 2.0 MHz.

```
0001:  2.0
0002:  -90  0.5
0003:  -90-17.0
0004:  -89  0.5
0005:  -87-16.7
0006:  -88  0.5
0007:  -88-16.3
0008:  -87  0.5
0009:  -87-16.0
0010:  -86  0.5
0011:  -86-15.7
0012:  -85  0.6
0013:  -85-15.4
0014:  -84  0.6
0015:  -84-15.0
0016:  -83  0.6
0017:  -83-14.7
0018:  -82  0.6
0019:  -82-14.3
0020:  -81  0.6
0021:  -81-14.0
0022:  -80  0.6
0023:  -80-13.6
0024:  -79  0.6
0025:  -79-13.1
0026:  -78  0.6
0027:  -78-12.4
0028:  -77  0.6
0029:  -77-11.8
0030:  -76  0.6
0031:  -76-11.8
0032:  -75  0.6
0033:  -75-10.5
0034:  -74  0.6
0035:  -74 -9.8
0036:  -73  0.6
0037:  -73 -9.2
0038:  -72  0.6
0039:  -72 -8.5
0040:  -71  0.6
0041:  -71 -7.9
0042:  -70  0.6
0043:  -70 -7.3
0044:  -69  0.6
0045:  -69 -7.1
0046:  -68  0.6
0047:  -68 -6.8
0048:  -67  0.6
0049:  -67 -6.6
0050:  -66  0.6
0051:  -66 -6.3
0052:  -65  0.6
0053:  -65 -6.1
0054:  -64  0.6
0055:  -64 -5.9
0056:  -63  0.6
0057:  -63 -5.7
0058:  -62  0.6
0059:  -62 -5.4
0060:  -61  0.6
0061:  -61 -5.2
0062:  -60  0.6
0063:  -60 -4.9
0064:  -59  0.5
0065:  -59 -4.8
0066:  -58  0.5
0067:  -58 -4.7
0068:  -57  0.4
0069:  -57 -4.6
0070:  -56  0.4
0071:  -56 -4.6
0072:  -55  0.3
0073:  -55 -4.5
0074:  -54  0.3
0075:  -54 -4.4
0076:  -53  0.2
0077:  -53 -4.4
0078:  -52  0.1
0079:  -52 -4.3
0080:  -51  0.1
0081:  -51 -4.2
0082:  -50 00.0
0083:  -50 -4.2
0084:  -49 -0.1
0085:  -49 -4.0
0086:  -48 -0.2
0087:  -48 -3.8
0088:  -47 -0.3
0089:  -47 -3.6
0090:  -46 -0.4
0091:  -46 -3.5
0092:  -45 -0.5
0093:  -45 -3.4
0094:  -44 -0.5
0095:  -44 -3.2
0096:  -43 -0.6
0097:  -43 -3.0
0098:  -42 -0.7
0099:  -42 -2.9
0100:  -41 -0.8
0101:  -41 -2.7
0102:  -40 -0.9
0103:  -40 -2.5
0104:  -39 -1.1
0105:  -39 -2.3
0106:  -38 -1.3
0107:  -38 -2.2
0108:  -37 -1.4
0109:  -37 -2.1
0110:  -36 -1.6
0111:  -36 -2.0
0112:  -35 -1.7
0113:  -35 -1.8
0114:  -34 -1.9
0115:  -34 -1.7
0116:  -33 -2.0
0117:  -33 -1.6
0118:  -32 -2.2
0119:  -32 -1.4
0120:  -31 -2.4
0121:  -31 -1.3
0122:  -30 -2.6
0123:  -30 -1.2
0124:  -29 -2.8
0125:  -29 -1.2
0126:  -28 -3.0
0127:  -28 -1.2
0128:  -27 -3.3
0129:  -27 -1.2
0130:  -26 -3.5
0131:  -26 -1.2
0132:  -25 -3.7
0133:  -25 -1.1
0134:  -24 -4.0
0135:  -24 -1.1
0136:  -23 -4.2
0137:  -23 -1.1
0138:  -22 -4.4
0139:  -22 -1.1
0140:  -21 -4.6
0141:  -21 -1.1
0142:  -20 -4.8
0143:  -20 -1.1
0144:  -19 -5.0
0145:  -19 -1.1
0146:  -18 -5.2
0147:  -18 -1.1
0148:  -17 -5.5
0149:  -17 -1.1
0150:  -16 -5.7
0151:  -16 -1.1
0152:  -15 -6.0
0153:  -15 -1.0
0154:  -14 -6.2
0155:  -14 -1.0
0156:  -13 -6.4
0157:  -13 -1.0
0158:  -12 -6.6
0159:  -12 -1.0
0160:  -11 -6.9
0161:  -11 -1.0
0162:  -10 -7.1
0163:  -10 -1.0
0164:  -09 -7.2
0165:   -9 -1.0
0166:  -08 -7.3
0167:   -8 -1.0
0168:  -07 -7.4
0169:   -7 -1.0
0170:  -06 -7.5
0171:   -6 -1.0
0172:  -05 -7.5
0173:   -5 -0.9
0174:  -04 -7.6
0175:   -4 -0.9
0176:  -03 -7.7
0177:   -3 -0.9
0178:  -02 -7.8
0179:   -2 -0.9
0180:  -01 -7.9
0181:   -1 -0.9
0182:  -00 -8.0
0183:    0 -0.9
0184:    1 -8.0
0185:    1 -0.9
0186:    2 -8.0
0187:    2 -0.9
0188:    3 -8.0
0189:    3 -0.9
0190:    4 -8.0
0191:    4 -0.9
0192:    5 -8.0
0193:    5 -0.9
0194:    6 -8.0
0195:    6 -0.8
0196:    7 -8.0
0197:    7 -0.8
0198:    8 -8.0
0199:    8 -0.8
0200:    9 -8.0
0201:    9 -0.8
0202:   10 -8.0
0203:   10 -0.9
0204:   11 -8.0
0205:   11 -0.8
0206:   12 -7.9
0207:   12 -0.8
0208:   13 -7.9
0209:   13 -0.9
0210:   14 -7.9
0211:   14 -0.9
0212:   15 -7.8
0213:   15 -0.9
0214:   16 -7.8
0215:   16 -0.9
0216:   17 -7.8
0217:   17 -0.9
0218:   18 -7.7
0219:   18 -1.0
0220:   19 -7.7
0221:   19 -1.0
0222:   20 -7.6
0223:   20 -1.0
0224:   21 -7.4
0225:   21 -1.1
0226:   22 -7.1
0227:   22 -1.3
0228:   23 -6.9
0229:   23 -1.4
0230:   24 -6.6
0231:   24 -1.6
0232:   25 -6.4
0233:   25 -1.7
0234:   26 -6.1
0235:   26 -1.8
0236:   27 -5.9
0237:   27 -2.0
0238:   28 -5.6
0239:   28 -2.1
0240:   29 -5.4
0241:   29 -2.3
0242:   30 -5.1
0243:   30 -2.4
0244:   31 -5.0
0245:   31 -2.6
0246:   32 -4.9
0247:   32 -2.7
0248:   33 -4.8
0249:   33 -2.9
0250:   34 -4.7
0251:   34 -3.0
0252:   35 -4.5
0253:   35 -3.2
0254:   36 -4.4
0255:   36 -3.3
0256:   37 -4.3
0257:   37 -3.5
0258:   38 -4.2
0259:   38 -3.6
0260:   39 -4.1
0261:   39 -3.8
0262:   40 -4.0
0263:   40 -3.9
0264:   41 -3.8
0265:   41 -4.0
0266:   42 -3.6
0267:   42 -4.1
0268:   43 -3.4
0269:   43 -4.2
0270:   44 -3.2
0271:   44 -4.4
0272:   45 -3.0
0273:   45 -4.5
0274:   46 -2.9
0275:   46 -4.6
0276:   47 -2.7
0277:   47 -4.8
0278:   48 -2.5
0279:   48 -4.9
0280:   49 -2.3
0281:   49 -5.0
0282:   50 -2.1
0283:   50 -5.1
0284:   51 -2.0
0285:   51 -5.4
0286:   52 -1.9
0287:   52 -5.7
0288:   53 -1.8
0289:   53 -6.0
0290:   54 -1.7
0291:   54 -6.3
0292:   55 -1.6
0293:   55 -6.6
0294:   56 -1.6
0295:   56 -6.8
0296:   57 -1.5
0297:   57 -7.1
0298:   58 -1.4
0299:   58 -7.4
0300:   59 -1.3
0301:   59 -7.6
0302:   60 -1.2
0303:   60 -7.9
0304:   61 -1.1
0305:   61 -8.4
0306:   62 -1.0
0307:   62 -8.8
0308:   63 -0.8
0309:   63 -9.3
0310:   64 -0.7
0311:   64 -9.7
0312:   65 -0.6
0313:   65-10.2
0314:   66 -0.5
0315:   66-10.6
0316:   67 -0.4
0317:   67-11.1
0318:   68 -0.2
0319:   68-11.5
0320:   69 -0.1
0321:   69-12.0
0322:   70  0.0
0323:   70-12.4
0324:   71  0.0
0325:   71-13.0
0326:   72  0.0
0327:   72-13.7
0328:   73  0.0
0329:   73-14.3
0330:   74 00.0
0331:   74-15.0
0332:   75  0.0
0333:   75-15.6
0334:   76  0.1
0335:   76-16.3
0336:   77  0.1
0337:   77-17.0
0338:   78  0.1
0339:   78-17.7
0340:   79  0.1
0341:   79-18.4
0342:   80  0.1
0343:   80-19.1
0344:   81  0.1
0345:   81-19.0
0346:   82  0.1
0347:   82-18.9
0348:   83  0.1
0349:   83-18.8
0350:   84  0.1
0351:   84-18.7
0352:   85  0.1
0353:   85-18.6
0354:   86  0.2
0355:   86-18.6
0356:   87  0.2
0357:   87-18.5
0358:   88  0.2
0359:   88-18.4
0360:   89  0.2
0361:   89-18.4
0362:   90  0.2
0363:   90-18.3
```

```
REQUESTED OPTIONS: ID

OPTIONS IN EFFECT: NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(0228K) AUTODBL(NONE)
                   SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT GOSTMT NOXREF NOALC NOANSF TERMINAL FLAG(I)

 ISN 0002          SUBROUTINE BREM10(PLNGT,TLATD,TLONGD,RLATD,RLONGD,BER)          BRE00010
             C                                                                     BRE00020
             C     CONTROL PROGRAM FOR DIRECT RAY, REFLECTED RAY, AND              BRE00030
             C     GROUND WAVE FIELD STRENGTH CALCULATION BY THE METHOD OF         BRE00040
             C     BREMMER AND VAN DER POL.                                        BRE00050
             C                                                                     BRE00060
             C     ----------------------------------------------------------------BRE00070
             C                                                                     BRE00080
             C     LIMITATIONS-ELEMENTARY TRANSMITTING DIPOLE, 1.KW ERP, DISTANCE  BRE00090
             C     MEASURED IN KILOMETERS ALONG THE GREAT CIRCLE PATH, CONDUCTIVITY BRE00100
             C     MEASURED IN MHOS/METER, FREQUENCY IN MEGAHERTZ, ANTENNA HEIGHTS BRE00110
             C     IN METERS, DIELECTRIC CONSTANT IS DIMENSIONLESS.                BRE00120
             C     NOTE-IF ONE OF THE TERMINALS IS ON THE GROUND ASSUME IT TO BE THE BRE00130
             C     TRANSMITTER.                                                    BRE00140
             C                                                                     BRE00150
             C     ----------------------------------------------------------------BRE00160
 ISN 0003          REAL K,LAMBDA,LAT,LONG,MOIST                                    BRE00170
 ISN 0004          COMPLEX DELTA,J                                                 BRE00180
 ISN 0005          COMMON ERTHR,PI,RAD,DEG,PIBY2,TWOPI,REFIND,FREQ                 BRE00190
 ISN 0006          COMMON /BON/ LONG,LAT,GAMMA,GMT,IO                              BRE00200
 ISN 0007          COMMON /GWAVE/ SIGMA,EPSLON,THT,RHT,DKM,DLOS,THETA,LAMBDA,J     BRE00210
 ISN 0008          COMMON/PO/JK,KL,IFCT,GRLOSS,ALA1,ALA2,LLF,IHRC,P200,DB,HTCAL,JHOURBRE00220
                  1,RNOYS(80),FHNAME(12),BETA,TTT                                  BRE00230
 ISN 0009          DATA DMY1, DMY2, DMY3, DMY4, DMY5, DMY6 /6*0.0/                 BRE00240
 ISN 0010          J=(0.,1.)                                                       BRE00250
 ISN 0011          IO=2                                                            BRE00260
 ISN 0012          EH = -1.000                                                     BRE00270
 ISN 0013          EV = -1.000                                                     BRE00280
 ISN 0014          ELNOST = -1.000                                                 BRE00290
 ISN 0015          DBV = -1.E75                                                    BRE00300
 ISN 0016          DBH = -1.E75                                                    BRE00310
 ISN 0017          DBL = -1.E75                                                    BRE00320
 ISN 0018          TBD = 0.0                                                       BRE00330
 ISN 0019          TBR = 0.0                                                       BRE00340
 ISN 0020          RBR = 0.0                                                       BRE00350
 ISN 0021          RBD = 0.0                                                       BRE00360
 ISN 0022          READ(5,30) THT,RHT,SIGMA,EPSLON,WNDVEL,NSEGS,MPTS,FACHNZ        BRE00370
 ISN 0023       30 FORMAT(5F10.3,2I5,F10.3)                                        BRE00380
 ISN 0024          PRINT 35, THT, RHT, SIGMA, EPSLON, WNDVEL, NSEGS, MPTS          BRE00390
 ISN 0025       35 FORMAT(//56X,'BREM ANALYSIS INPUT',/,15X,'TRANS HEIGHT',3X,     BRE00400
                  1   'RCVR HEIGHT',8X,'SIGMA',9X,'EPSILON',7X,'WIND VEL',9X,      BRE00410
                  2   'SUDA',8X,'MILLINGTON',/16X,5(F10.3,5X),4X,I5,12X,I5)        BRE00420
             C                                                                     BRE00430
             C     IF EPSILON IS NOT PROVIDED, ZERO SIGMA TO TRIGGER COMPUTATION   BRE00440
             C                                                                     BRE00450
 ISN 0026          IF(EPSLON.LE.0.) SIGMA = 0.                                     BRE00460
 ISN 0028          IF(SIGMA.GT.2.0)                                                BRE00470
                  1  SIGMA = 2.778E-05/((2.635E-03 + WNDVEL*8.784E-05)**2)         BRE00480
 ISN 0030          ZT = THT*0.001 + ERTHR                                          BRE00490
 ISN 0031          ZR = RHT*0.001 + ERTHR                                          BRE00500
 ISN 0032          DKM = PLNGT                                                     BRE00510
 ISN 0033          LAMBDA=300./FREQ                                                BRE00520
 ISN 0034          THETA = DKM/ERTHR                                               BRE00530
```

```
ISN 0035          THETA1=ARCOS(ERTHR/ZT)                                          BRE00540
ISN 0036          DLOS=SQRT((ZT**2)+(ZR**2)-2.*ZT*ZR*COS(THETA))                  BRE00550
             C  IF RECEIVER IS BEYOND HORIZON GO TO NEXT LOGIC STEP               BRE00560
ISN 0037          IF(THETA.GT.THETA1) GO TO 150                                   BRE00570
             C                                                                    BRE00580
             C    COMPUTE LINE OF SIGHT VOLTAGE AND ZENITH ANGLES AT TRANSMITTER  BRE00590
             C        AND RECEIVER                                                BRE00600
             C                                                                    BRE00610
ISN 0039          ELNOST = 1.5E05/DLOS                                            BRE00620
ISN 0040          SINX = ZT*SIN(THETA)/DLOS                                       BRE00630
ISN 0041          IF(SINX.GT.1.0000) SINX = 1.0000                                BRE00640
ISN 0043          RBD = PIBY2 - ARSIN(SINX)                                       BRE00650
ISN 0044          SINX = ZR*SIN(THETA)/DLOS                                       BRE00660
ISN 0045          IF(SINX.GT.1.0000) SINX = 1.0000                                BRE00670
ISN 0047          TBD = PIBY2 - ARSIN(SINX)                                       BRE00680
             C                                                                    BRE00690
             C    CORRECT QUADRANT ON DIRECT ANGLES UNLESS ONE IS UPGOING         BRE00700
             C                                                                    BRE00710
ISN 0048          IF(THT.LE.RHT) RBD = - RBD                                      BRE00720
ISN 0050          IF(RHT.LE.THT) TBD = - TBD                                      BRE00730
ISN 0052          IF(RHT.LE.0.) GO TO 500                                         BRE00740
             C                                                                    BRE00750
             C    IF BOTH ANTENNAS ARE ELEVATED COMPUTE POWER AND ZENITH ANGLES   BRE00760
             C    FOR REFLECTED RAY ALSO                                          BRE00770
             C                                                                    BRE00780
ISN 0054          CALL RFLXRA(TLATD,TLONGD,RER,WNOVEL,TBR,RBR,EH,EV)              BRE00790
             C                                                                    BRE00800
             C  PROCEED TO REPORT SECTOR                                          BRE00810
ISN 0055          GOTO 500                                                        BRE00820
             C                                                                    BRE00830
             C    RECEIVER IS BEYOND HORIZON, COMPUTE HORIZON TRANSITION CRITERION BRE00840
             C                                                                    BRE00850
ISN 0056      150 CONTINUE                                                        BRE00860
ISN 0057          DTHETA = THETA - THETA1                                         BRE00870
ISN 0058          DELX = ERTHR*SQRT((1./COS(DTHETA))**2 - 1.)                     BRE00880
ISN 0059          DELH = DELX*SIN(0.1*RAD)/COS(0.1*RAD + DTHETA)                  BRE00890
ISN 0060          TRANS = 1000.*(DELH + ERTHR*(1./COS(DTHETA) -1.))               BRE00900
             C                                                                    BRE00910
             C  IF RECEIVER IS BELOW LINE OF SIGHT MOVE ON TO GROUND WAVE LOGIC   BRE00920
ISN 0061          IF(RHT.LE.TRANS) GOTO 200                                       BRE00930
             C                                                                    BRE00940
             C                                                                    BRE00950
             C    COMPUTE LINE OF SIGHT VOLTAGE AND ZENITH ANGLES AT TRANSMITTER  BRE00960
             C        AND RECEIVER                                                BRE00970
             C                                                                    BRE00980
ISN 0063          ELNOST = 1.5E05/DLOS                                            BRE00990
ISN 0064          SINX = ZT*SIN(THETA)/DLOS                                       BRE01000
ISN 0065          IF(SINX.GT.1.0000) SINX = 1.0000                                BRE01010
ISN 0067          RBD = PIBY2 - ARSIN(SINX)                                       BRE01020
ISN 0068          SINX = ZR*SIN(THETA)/DLOS                                       BRE01030
ISN 0069          IF(SINX.GT.1.0000) SINX = 1.0000                                BRE01040
ISN 0071          TBD = PIBY2 - ARSIN(SINX)                                       BRE01050
             C                                                                    BRE01060
             C    CORRECT QUADRANT ON DIRECT ANGLES UNLESS ONE IS UPGOING         BRE01070
             C                                                                    BRE01080
ISN 0072          IF(THT.LE.RHT) RBD = - RBD                                      BRE01090
ISN 0074          IF(RHT.LE.THT) TBD = - TBD                                      BRE01100
ISN 0076          IF(THT.LE.0.) GO TO 500                                         BRE01110
```

```
                 C                                                                     BRE01120
                 C      IF BOTH ANTENNAS ARE ELEVATED COMPUTE POWER AND ZENITH ANGLES  BRE01130
                 C      FOR REFLECTED RAY ALSO                                         BRE01140
                 C                                                                     BRE01150
  ISN 0078              CALL RFLXRA(TLATD,TLONGD,BER,WNDVEL,TBR,RBR,EH,EV)             BRE01160
                 C                                                                     BRE01170
                 C  PROCEED TO REPORT SECTION                                          BRE01180
  ISN 0079              GO TO 500                                                      BRE01190
  ISN 0080          200 CONTINUE                                                       BRE01200
                 C  DETERMINE SIGMA AND EPSILON VALUES FOR GROUND WAVE CALCULATIONS    BRE01210
  ISN 0081              IF(SIGMA.LE.0.) GO TO 210                                      BRE01220
                 C                                                                     BRE01230
                 C      USER PROVIDED SIGMA AND EPSILON: DETERMINE GROUNDWAVE FIELD VALUESBRE01240
                 C                                                                     BRE01250
  ISN 0083              CALL GRNDWV(EH,EV)                                             BRE01260
  ISN 0084              GO TO 500                                                      BRE01270
  ISN 0085          210 CONTINUE                                                       BRE01280
                 C                                                                     BRE01290
                 C  SIGMA NOT PROVIDED USE METHOD OF SUDA OR MOM DEPENDING ON MPTS     BRE01300
                 C                                                                     BRE01310
  ISN 0086              IF(NSEGS.LE.0)  GO TO 9901                                     BRE01320
  ISN 0088              PRINT 211                                                      BRE01330
  ISN 0089          211 FORMAT(//21X,'LATITUDE',6X,'LONGITUDE',9X,'SIGMA',9X,'EPSILON')  BRE01340
  ISN 0090              PRINT 212                                                      BRE01350
  ISN 0091          212 FORMAT(//5X,'FROM TRANSMITTER'//)                              BRE01360
  ISN 0092              SEGLNT = PLNGT/NSEGS                                           BRE01370
  ISN 0093              IF(MPTS.GT.0.) GO TO 220                                       BRE01380
                 C                                                                     BRE01390
                 C      USE THE METHOD OF SUDA WITH NSEGS + 1 POINTS                   BRE01400
                 C                                                                     BRE01410
  ISN 0095              NSEGS = NSEGS + 1                                              BRE01420
  ISN 0096              CALL ASGEPS(SEGLNT,NSEGS,TLATD,TLONGD,BER,WNDVEL,SIGMA,EPSLON)  BRE01430
  ISN 0097              CALL GRNDWV(EH,EV)                                             BRE01440
  ISN 0098              GO TO 500                                                      BRE01450
                 C                                                                     BRE01460
                 C      USE  THE METHOD OF MILLINGTON TO DETERMINE SIGMA AND EPSILON   BRE01470
                 C                                                                     BRE01480
  ISN 0099          220 CONTINUE                                                       BRE01490
                 C                                                                     BRE01500
                 C   FUTHER SUBDIVIDE THE SEGMENTS INTO MPTS STEPS FOR AVERAGING VALUES  BRE01510
                 C                                                                     BRE01520
  ISN 0100              MDIST =SEGLNT/MPTS                                             BRE01530
                 C                                                                     BRE01540
                 C   DO CALCULATIONS ONCE FOR TRANSMITTER AND ONCE FOR RECEIVER        BRE01550
                 C                                                                     BRE01560
                 C   AVERAGE SIGMA AND EPSILON VALUES DETERMINED AT MPTS + 1 POINTS    BRE01570
                 C    WITHIN ONE SEGLNGT OF THE TRANS/RCVR                             BRE01580
                 C                                                                     BRE01590
  ISN 0101              MPTS = MPTS + 1                                                BRE01600
  ISN 0102              CALL ASGEPS(MDIST,MPTS,TLATD,TLONGD,BER,WNDVEL,SIGMA,EPSLON)   BRE01610
                 C                                                                     BRE01620
                 C      SAVE 'E''S COMPUTED WITH TRANSMITTER VALUES FOR LATER USE      BRE01630
                 C                                                                     BRE01640
  ISN 0103              CALL GRNDWV(ETH,ETV)                                           BRE01650
                 C                                                                     BRE01660
                 C   FIND STARTING POINTS FOR RECEIVER CALCULATIONS                    BRE01670
                 C                                                                     BRE01680
  ISN 0104              DIST = (NSEGS - 1)*SEGLNT                                      BRE01690
```

```
ISN 0105          CALL COOR(TLATD,TLONGD,BER,DIST,RLAT,RLONG)                    BRE01700
ISN 0106          PRINT 224                                                      BRE01710
ISN 0107      224 FORMAT(//5X,'TOWARD RECEIVER'//)                               BRE01720
ISN 0108          CALL ASGEPS(MDIST,MPTS,RLAT,RLONG,BER,WNDVEL,SIGMA,EPSLON)     BRE01730
ISN 0109          CALL GRNDWV(EH,EV)                                             BRE01740
ISN 0110          EH = SQRT(ETH**2 + EH**2)                                      BRE01750
ISN 0111          EV = SQRT(ETV**2 + EV**2)                                      BRE01760
            C                                                                    BRE01770
            C     PROCEED WITH POWER CALCULATIONS AND REPORTING                  BRE01780
            C                                                                    BRE01790
ISN 0112      500 CONTINUE                                                       BRE01800
            C                                                                    BRE01810
            C     COMPUTE RECEIVED POWER IN 'DBW' ASSUMING                       BRE01820
            C         A 1 WATT ISOTROPIC RATIATOR                                BRE01830
            C                                                                    BRE01840
ISN 0113          FLDK = -188.516 + 20.*ALOG10(LAMBDA)                           BRE01850
ISN 0114          IF(ELNDST.GT.0.0) DBL = 20.*ALOG10(ELNDST) + FLDK              BRE01860
ISN 0116          IF(EV.GT.0.0) DBV = 20.*ALOG10(EV) + FLDK                      BRE01870
ISN 0118          IF(EH.GT.0.0) DBH = 20.*ALOG10(EH) + FLDK                      BRE01880
            C                                                                    BRE01890
            C       CONVERT RADIANS TO DEGREES FOR OUTPUT                        BRE01900
            C                                                                    BRE01910
ISN 0120          TBD = TBD*DEG                                                  BRE01920
ISN 0121          TBR = TBR*DEG                                                  BRE01930
ISN 0122          RBD = RBD*DEG                                                  BRE01940
ISN 0123          RBR = RBR*DEG                                                  BRE01950
ISN 0124          PRINT 9010                                                     BRE01960
            C                                                                    BRE01970
            C     WRITE OUT RESULTS TO UNIT 7 FOR COMEFF                         BRE01980
            C                                                                    BRE01990
ISN 0125          WRITE(7,9100) TTT,FACHNZ,FREQ,BETA,DMY2,DMY3,THT,RHT,          BRE02000
                 1     RNOYS(IFCT),JHOUR,DMY6                                    BRE02010
ISN 0126          WRITE(7,9200) DBV,DBH,DBL,TBD,TBR,RBD,RBR                      BRE02020
ISN 0127          IF(DBL.GE.-1.E74) GO TO 510                                    BRE02030
            C                                                                    BRE02040
            C     PRINTOUT FOR GROUNDWAVE                                        BRE02050
            C                                                                    BRE02060
ISN 0129          PRINT 9011, DBV,DBH,TBD,RBD                                    BRE02070
ISN 0130          RETURN                                                         BRE02080
ISN 0131      510 CONTINUE                                                       BRE02090
ISN 0132          IF(THT.GT.0.00.AND.RHT.GT.0.00) GO TO 520                      BRE02100
            C                                                                    BRE02110
            C     PRINTOUT FOR LINE OF SIGHT ONLY CASE                           BRE02120
            C                                                                    BRE02130
ISN 0134          PRINT 9012, DBL, TBD, RBD                                      BRE02140
ISN 0135          RETURN                                                         BRE02150
ISN 0136      520 CONTINUE                                                       BRE02160
            C                                                                    BRE02170
            C     PRINTOUT FOR LINE OF SIGHT AND REFLECTED RAY CASE              BRE02180
            C                                                                    BRE02190
ISN 0137          PRINT 9013,DBV,DBH,DBL,TBD,TBR,RBD,RBR                         BRE02200
ISN 0138          RETURN                                                         BRE02210
ISN 0139     9010 FORMAT(//56X,21HBREM ANALYSIS RESULTS,/28X,                    BRE02220
                 1   25HRELATIVE POWER COMPONENTS,38X,17HRAY ZENITH ANGLES,/18X, BRE02230
                 2   12HPOLARIZATION,20X,13HLINE OF SIGHT,16X,11HTRANSMITTER,20X, BRE02240
                 3   8HRECEIVER,/10X,8HVERTICAL,10X,10HHORIZONTAL,28X,           BRE02250
                 4   2(8X,6HDIRECT,7X,9HREFLECTED),/13X,3HDBW,16X,3HDBW,20X,3HDBW, BRE02260
                 5   11X,4(4X,7HDEGREES,4X))                                     BRE02270
```

```
ISN 0140      9011 FORMAT(1H0,4X,2(G15.3,5X),20X,F15.3,15X,F15.3)          BRE02280
ISN 0141      9012 FORMAT (1H0,44X,G15.3,F15.3,15X,F15.3)                  BRE02290
ISN 0142      9013 FORMAT(1H0,4X,3(G15.3,5X),4F15.3)                       BRE02300
ISN 0143      9100 FORMAT(1HG,F6.0,F10.3,3F6.2,2F7.1,F9.1,F7.1,I5,F10.1)   BRE02310
ISN 0144      9200 FORMAT(1H3,3G12.6,4F10.3)                               BRE02320
ISN 0145           RETURN                                                  BRE02330
ISN 0146      9901 CONTINUE                                                BRE02340
ISN 0147           PRINT 9902, FREQ,SIG,THT,RHT,NSEGS,MPTS                 BRE02350
ISN 0148      9902 FORMAT(//10X,'STOP : INSUFFICIENT DATA', 4F10.4//)      BRE02360
ISN 0149           STOP                                                    BRE02370
ISN 0150           END                                                     BRE02380
```

```
REQUESTED OPTIONS: ID

OPTIONS IN EFFECT: NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(0228K) AUTODBL(NONE)
                   SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT GOSTMT NOXREF NOALC NOANSF TERMINAL FLAG(I)

  ISN 0002             SUBROUTINE RFLXRA(TRANSX,TRANSY,BER,WNDVEL,TBR,RBR,EH,EV)      BRE02390
                 C                                                                    BRE02400
                 C     THIS SUBROUTINE CALCULATES THE STRENGTH OF THE REFLECTED WAVE  BRE02410
                 C     WHEN THE RECEIVER IS IN LINE-OF-SIGHT OF THE TRANSMITTER.      BRE02420
                 C                                                                    BRE02430
                 C                                                                    BRE02440
  ISN 0003             REAL K,LAMBDA                                                  BRE02450
  ISN 0004             COMPLEX J,MUS,CFAC,CXRT,REF,EVAL,CONST                         BRE02460
  ISN 0005             COMMON ERTHR,PI,RAD,DEG,PIBY2,TWOPI,REFIND,FMC                 BRE02470
  ISN 0006             COMMON /BON/ YLOC,XLOC,GAMMA,GMT,IO                            BRE02480
  ISN 0007             COMMON /GWAVE/ SIGMA,EPSLON,THT,RHT,DKM,DLOS,THETA,LAMBDA,J    BRE02490
  ISN 0008             POLAR = -1.                                                    BRE02500
                 C                                                                    BRE02510
                 C   FIND ANGLE OF INCIDENCE PLUS TAU1 AND TAU4                       BRE02520
                 C                                                                    BRE02530
  ISN 0009             ZT = ERTHR + THT*0.001                                         BRE02540
  ISN 0010             ZR = ERTHR + RHT*0.001                                         BRE02550
  ISN 0011             HSUM = THT + RHT                                               BRE02560
  ISN 0012             HSUMS = THT**2 + RHT**2                                        BRE02570
  ISN 0013             HSSUM = (THT + RHT)**2                                         BRE02580
  ISN 0014             DSTOHT = 1000.*DKM/HSUM                                        BRE02590
  ISN 0015             ARGT2 = DSTOHT + THETA*(HSUMS/HSSUM)*(1. + (DSTOHT**2)/2.)     BRE02600
  ISN 0016             TAU2=ATAN(ARGT2)                                               BRE02610
  ISN 0017             ARGT1=(ERTHR/ZT)*SIN(TAU2)                                     BRE02620
  ISN 0018             ARGT4=(ERTHR/ZR)*SIN(TAU2)                                     BRE02630
  ISN 0019             TAU1=ARSIN(ARGT1)                                              BRE02640
  ISN 0020             TAU4=ARSIN(ARGT4)                                              BRE02650
                 C                                                                    BRE02660
                 C    CALCULATE TRANSMITTER PROPOGATION ANGLES                        BRE02670
                 C                                                                    BRE02680
  ISN 0021             TBR = TAU1 - PIBY2                                             BRE02690
                 C                                                                    BRE02700
                 C    CALCULATE RECEIVER ANGLES                                       BRE02710
                 C                                                                    BRE02720
  ISN 0022             RBR = TAU4 - PIBY2                                             BRE02730
                 C                                                                    BRE02740
                 C  FIND SIGMA AND EPSILON IF THEY HAVE NOT BEEN PROVIDED             BRE02750
                 C                                                                    BRE02760
  ISN 0023             IF (SIGMA.GT.0.) GOTO 100                                      BRE02770
  ISN 0025             RFLXPT = ERTHR*(TAU2 - TAU1)                                   BRE02780
  ISN 0026             CALL COOR(TRANSX,TRANSY,BER,RFLXPT,DLAT,DLNG)                  BRE02790
  ISN 0027             XLOC = DLAT*RAD                                                BRE02800
  ISN 0028             YLOC = DLNG*RAD                                                BRE02810
  ISN 0029             CALL NWOMAP                                                    BRE02820
  ISN 0030             CALL FSGEPS(GAMMA,SIGMA,EPSLON,WNDVEL)                         BRE02830
  ISN 0031             PRINT 95, DLAT,DLNG,SIGMA,EPSLON                               BRE02840
  ISN 0032          95 FORMAT(//15X,'REFLECTED RAY CALCULATIONS:'/20X,                BRE02850
                      1   'AT LAT ',F8.3,'  AND LONG ',F8.3,                          BRE02860
                      2  '    SIGMA = ',F7.3,'   EPSILON = ',F8.3,' (EFFECTIVE VALUES)'//)BRE02870
  ISN 0033         100 CONTINUE                                                       BRE02880
                 C                                                                    BRE02890
                 C   PROCEED WITH VOLTAGE CALCULATIONS                                BRE02900
                 C                                                                    BRE02910
```

```
LEVEL 2.1  ( JAN 75 )         RFLXRA          OS/360  FORTRAN H EXTENDED           DATE 77.271/15.29.55        PAGE   2

  ISN 0034           D1=(ZT*COS(TAU1))-(ERTHR*COS(TAU2))
  ISN 0035           D2=(ZR*COS(TAU4))-(ERTHR*COS(TAU2))
  ISN 0036           DSUM = D2 + D1
  ISN 0037           CTGPSI = (D2 - D1)*COTAN(TAU2)/DSUM
  ISN 0038           SINPSI = 1./SQRT(1. + CTGPSI**2)
  ISN 0039           DEL = DLOS*((SINPSI/SIN(TAU2)) - 1.)
  ISN 0040           ALPHA = ERTHR*DSUM*SQRT(SIN(TAU2)*COS(TAU2))/
                    1   SQRT(ZT*ZR*SIN(THETA)*((D1*ZR*COS(TAU4)) + (D2*ZT*COS(TAU1))))
  ISN 0041           WRK = 60.0*SIGMA*LAMBDA
  ISN 0042           PHI = ATAN(WRK/EPSLON)
  ISN 0043           MUS = SQRT(EPSLON**2 + WRK**2)*CEXP(J*PHI)
  ISN 0044           CXRT = CSQRT(MUS - SIN(TAU2)**2)
  ISN 0045           CFAC = CEXP(2.*J*PI*DEL*1000./LAMBDA)
  ISN 0046           CONST = 1.5*ALPHA*CFAC/DSUM
               C    COMPUTE REF FOR HORIZONTAL POLARIZATION
  ISN 0047           REF = (COS(TAU2) - CXRT)/(COS(TAU2) + CXRT)
  ISN 0048           XCOS = COS(TAU2)
               C     PRINT 117
               C 117 FORMAT(5X,'*****REFLECTED RAY*****')
               C     PRINT 118,XCOS,CXRT,REF
               C 118 FORMAT(5X,'COS(TAU2)=',F10.5,5X,'CXRT=',2F10.5,5X,'REF=',2F10.5)
  ISN 0049           GO TO 125
  ISN 0050       120 CONTINUE
               C     COMPUTE REF FOR VERTICAL POLARIZATION
  ISN 0051                REF = (MUS*COS(TAU2) - CXRT)/(MUS*COS(TAU2) + CXRT)
               C     PRINT 119
               C 119 FORMAT(5X,'VERTICAL POLARIZATION INGREDIENTS')
  ISN 0052           XCOS = COS(TAU2)
               C     PRINT 121,MUS,XCOS,CXRT,REF
               C 121 FORMAT(5X,'MUS=',2F10.5,5X,'COS(TAU2)=',F10.5,5X,'CXRT=',2F10.5,
               C    .   5X,'REF=',2F10.5)
  ISN 0053       125 CONTINUE
  ISN 0054           EVAL = CABS(CONST*REF)*100000.
  ISN 0055           IF(POLAR.GT.0.) GO TO 150
  ISN 0057           FH = FVAL
  ISN 0058           POLAR = 1.
  ISN 0059           GO TO 120
  ISN 0060       150 CONTINUE
  ISN 0061           EV = FVAL
  ISN 0062           RETURN
  ISN 0063           END

*OPTIONS IN EFFECT*NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(0228K) AUTODBL(NONE)

*OPTIONS IN EFFECT*SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT GOSTMT NOXREF NOALC NOANSF TERMINAL FLAG(I)

*STATISTICS*     SOURCE STATEMENTS =      62, PROGRAM SIZE =     3236, SUBPROGRAM NAME =RFLXRA

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                                  112K BYTES OF CORE NOT USED
```

```
LEVEL 2.1  ( JAN 75 )                        OS/360  FORTRAN H EXTENDED              DATE 77.271/15.30.55        PAGE   1

REQUESTED OPTIONS: ID

OPTIONS IN EFFECT: NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(0228K) AUTODBL(NONE)
                   SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT GOSTMT NOXREF NOALC NOANSF TERMINAL FLAG(I)

  ISN 0002            SUBROUTINE GRNDWV(FH,FV)                                          BRE03330
              C       THIS SUBROUTINE CALCULATES THE FIELD OF THE GROUND WAVE WHEN THE  BRE03340
              C       RECEIVER IS CLOSE TO OR BELOW THE HORIZON.                        BRE03350
              C                                                                         BRE03360
  ISN 0003            DIMENSION TAUI(15),TAUR(15),EXPR(15),EXPIM(15),X1(15),X2(15)      BRE03370
  ISN 0004            REAL K, LAMBDA, LAT, LONG                                         BRE03380
  ISN 0005            COMPLEX DELTA,J,TAU(15),HGFP(15),E1,E(15)                         BRE03390
  ISN 0006            COMPLEX*16 Z0(15),Z1(15),Z2(15),H10(15),H11(15),H12(15),H2(15),   BRE03400
                     1H1P(15),H2P(15)                                                   BRE03410
  ISN 0007            COMMON ERTHR,PI,RAD,DEG,PIBY2,TWOPI,REFIND,FREQ                   BRE03420
  ISN 0008            COMMON /BON/ LONG,LAT,GAMMA,GMT,IO                                BRE03430
  ISN 0009            COMMON /GWAVE/ SIGMA,EPSLON,THT,RHT,DKM,DLOS,THETA,LAMBDA,J       BRE03440
  ISN 0010            COEF1=0.333333                                                    BRE03450
  ISN 0011            COEF2=0.666666                                                    BRE03460
  ISN 0012            COEF3=0.62996053                                                  BRE03470
  ISN 0013            CHI=0.0537*DLOS/(LAMBDA**COEF1)                                   BRE03480
  ISN 0014            CHIS1 = THT*0.03674/LAMBDA**COEF2                                 BRE03490
  ISN 0015            CHIS2 = RHT*0.03674/LAMBDA**COEF2                                 BRE03500
  ISN 0016            WRK = 60.0*SIGMA*LAMBDA                                           BRE03510
              C                                                                         BRE03520
              C       SET UP FOR HORIZONTAL POLARIZATION CALCULATIONS                   BRE03530
              C                                                                         BRE03540
  ISN 0017            POLAR = -1.0                                                      BRE03550
  ISN 0018            PSY = (PI - ATAN((EPSLON - 1.)/WRK))/2.                           BRE03560
  ISN 0019            K = 0.002924*(LAMBDA**COEF1)/SQRT(SQRT((EPSLON - 1.)**2 + WRK**2))BRE03570
              C       PRINT 122                                                         BRE03580
              C 122 FORMAT(5X,'GROUND WAVE'/5X,'HORIZONTAL POLARIZATION INGREDIENTS') BRE03590
              C       PRINT 123,PSY,K                                                   BRE03600
              C 123 FORMAT(5X,'PSY=',F10.5,5X,'K=',F10.5)                               BRE03610
              C                                                                         BRE03620
              C       CALCULATION OF COMPONENT FACTORS                                  BRE03630
              C                                                                         BRE03640
  ISN 0020        100 CONTINUE                                                          BRE03650
  ISN 0021            WRK2=0.25*PI+PSY                                                  BRE03660
  ISN 0022            WRK3=75.*PI/180.+3.*PSY                                           BRE03670
  ISN 0023            WRK4=75.*PI/180.-5.*PSY                                           BRE03680
  ISN 0024            WRK5=15.*PI/180.-PSY                                              BRE03690
  ISN 0025            WRK6=60.*PI/180.-4.*PSY                                           BRE03700
  ISN 0026            WRK7=4.*PSY                                                       BRE03710
  ISN 0027            WRK8=2.*PSY                                                       BRE03720
  ISN 0028            WRK9=15.*PI/180.+3.*PSY                                           BRE03730
              C                                                                         BRE03740
  ISN 0029            IF(K.GE.0.6) GO TO 120                                            BRE03750
              C                                                                         BRE03760
              C       CALCULATIONS WHEN 'K' LESS THAN 0.6                               BRE03770
              C                                                                         BRE03780
  ISN 0031            TAUR(1)=0.928+K*COS(WRK2)+1.237*K**3.*COS(WRK3)-0.5*K**4.*COS(WRK7BRE03790
                     1)-2.755*K**5.*COS(WRK4)                                           BRE03800
  ISN 0032            TAUR(2)=1.622+K*COS(WRK2)+2.163*K**3.*COS(WRK3)-0.5*K**4.*COS(WRK7BRE03810
                     1)-8.422*K**5.*COS(WRK4)                                           BRE03820
  ISN 0033            TAUR(3)=2.191+K*COS(WRK2)+2.921*K**3.*COS(WRK3)-0.5*K**4.*COS(WRK7BRE03830
                     1)-15.36*K**5.*COS(WRK4)                                           BRE03840
  ISN 0034            TAUI(1)=1.607-K*SIN(WRK2)-1.237*K**3.*SIN(WRK3)+0.5*K**4.*SIN(WRK7BRE03850
```

```
                1)-2.755*K**5.*SIN(WRK4)                                         BRE03860
ISN 0035         TAUI(2)=2.810-K*SIN(WRK2)-2.163*K**3.*SIN(WRK3)+0.5*K**4.*SIN(WRK7BRE03870
                1)-8.422*K**5.*SIN(WRK4)                                         BRE03880
ISN 0036         TAUI(3)=3.795-K*SIN(WRK2)-2.921*K**3.*SIN(WRK3)+0.5*K**4.*SIN(WRK7BRE03890
                1)-15.36*K**5.*SIN(WRK4)                                         BRE03900
ISN 0037         DO 110 I = 4,15                                                  BRE03910
ISN 0038         TAUR(I)=1.116*((I+0.75)**COEF2)+K*COS(WRK2)                      BRE03920
ISN 0039         TAUI(I)=1.932*((I+0.75)**COEF2)-K*SIN(WRK2)                      BRE03930
ISN 0040     110 CONTINUE                                                         BRE03940
ISN 0041         GO TO 150                                                        BRE03950
            C                                                                     BRE03960
            C       CALCULATIONS WHEN  'K' GREATER THAN OR EQUAL TO 0.6           BRE03970
            C                                                                     BRE03980
ISN 0042     120 CONTINUE                                                         BRE03990
ISN 0043         TAUR(1)=0.4043+0.618*COS(WRK5)/K-0.236*SIN(WRK8)/K**2.-0.0533*COS(BRE04000
                1WRK9)/K**3.+0.00226*COS(WRK6)/K**4.                             BRE04010
ISN 0044         TAUR(2)=1.288+0.1940*COS(WRK5)/K-0.0073*SIN(WRK8)/K**2.+0.0120*COSBRE04020
                1(WRK9)/K**3.-0.00160*COS(WRK6)/K**4.                            BRE04030
ISN 0045         TAUI(1)=0.7003-0.6183*SIN(WRK5)/K+0.2364*COS(WRK8)/K**2.-0.0533*SIBRE04040
                1N(WRK9)/K**3.-0.00226*SIN(WRK6)/K**4.                           BRE04050
ISN 0046         TAUI(2)=2.232-0.1940*SIN(WRK5)/K+0.0073*COS(WRK8)/K**2.+0.0120*SINBRE04060
                1(WRK9)/K**3.+0.00160*SIN(WRK6)/K**4.                            BRE04070
ISN 0047         DO 130 I = 3,15                                                  BRE04080
ISN 0048         TAUR(I)=1.116*((I+0.25)**COEF2)+0.2241*COS(WRK5)/(K*((I+0.25)**  BRE04090
                1COEF2))                                                         BRE04100
ISN 0049         TAUI(I)=1.932*((I+0.25)**COEF2)-0.2241*SIN(WRK5)/(K*((I+0.25)**  BRE04110
                1COEF2))                                                         BRE04120
ISN 0050     130 CONTINUE                                                         BRE04130
            C                                                                     BRE04140
            C       CALCULATE E VECTOR COMPONENTS                                 BRE04150
            C                                                                     BRE04160
ISN 0051     150 CONTINUE                                                         BRE04170
ISN 0052         DELTA = K*CEXP(J*(0.75*PI - PSY))                                BRE04180
ISN 0053         DO 175 I = 1,15                                                  BRE04190
ISN 0054         TAU(I)=CMPLX(TAUR(I),TAUI(I))                                    BRE04200
ISN 0055         Z0(I)=-2.*COEF3*TAU(I)                                           BRE04210
ISN 0056         Z1(I)=COEF3*CHIS1+Z0(I)                                          BRE04220
ISN 0057         Z2(I)=COEF3*CHIS2+Z0(I)                                          BRE04230
ISN 0058         CALL MDHNKL(Z0(I),H10(I),H2(I),H1P(I),H2P(I))                    BRE04240
ISN 0059         CALL MDHNKL(Z1(I),H11(I),H2(I),H1P(I),H2P(I))                    BRE04250
ISN 0060         CALL MDHNKL(Z2(I),H12(I),H2(I),H1P(I),H2P(I))                    BRE04260
ISN 0061         HGFP(I)=H11(I)*H12(I)/H10(I)**2                                  BRE04270
ISN 0062         EXPR(I)=REAL(J*TAU(I)*CHI)                                       BRE04280
ISN 0063         EXPIM(I)=AIMAG(J*TAU(I)*CHI)                                     BRE04290
ISN 0064         IF(EXPR(I).LT.-170.) GO TO 160                                   BRE04300
ISN 0066         X1(I)=EXP(EXPR(I))                                               BRE04310
ISN 0067         X2(I)=CABS(2.*TAU(I)-1./DELTA**2)                                BRE04320
ISN 0068         IF((ALOG10(X1(I))-ALOG10(X2(I))).LT.-74.) GO TO 160              BRE04330
ISN 0070         E(I)=(752./DLOS)*SQRT(CHI)*HGFP(I)*CEXP(J*TAU(I)*CHI)/           BRE04340
                1(2.*TAU(I)-1./DELTA**2)                                         BRE04350
ISN 0071         GO TO 170                                                        BRE04360
ISN 0072     160 E(I) = (0.,0.)                                                   BRE04370
ISN 0073     170 CONTINUE                                                         BRE04380
            C    PRINT 171,POLAR,I,E(I)                                           BRE04390
            C 171 FORMAT(5X,'***** POLAR =',F5.1,5X,'E(',I2,')=',2G12.6)          BRE04400
ISN 0074     175 CONTINUE                                                         BRE04410
            C                                                                     BRE04420
            C       SUM E VECTOR COMPONENTS                                       BRE04430
```

```
                 C                                                                         BRE04440
   ISN 0075            E1=E(1)                                                             BRE04450
   ISN 0076            DO 180 I = 2,15                                                     BRE04460
   ISN 0077            E1=E1+E(I)                                                          BRE04470
   ISN 0078            E3=CABS(E1)*1.E03                                                   BRE04480
   ISN 0079            IF(E3.LT.1.E-03) GO TO 200                                          BRE04490
   ISN 0081        180 CONTINUE                                                            BRE04500
   ISN 0082        200 CONTINUE                                                            BRE04510
   ISN 0083            IF(POLAR.GT.0.) GO TO 220                                           BRE04520
                 C                                                                         BRE04530
                 C     SET UP FOR VERTICAL POLARIZATION                                    BRE04540
                 C                                                                         BRE04550
   ISN 0085            EH = E3                                                             BRE04560
   ISN 0086            POLAR = 1.                                                          BRE04570
   ISN 0087            PSY = ATAN(EPSLON/WRK) - ATAN((EPSLON - 1.)/WRK)/2.                 BRE04580
   ISN 0088            K = K*SQRT(EPSLON**2 + WRK**2)                                      BRE04590
                 C     PRINT 124,PSY,K                                                     BRE04600
                 C 124 FORMAT(5X,'VERTICAL POLARIZATION COMPONENTS'/5X,'PSY=',F10.5,5X,'KBRE04610
                 C    .=',F10.5)                                                           BRE04620
   ISN 0089            GO TO 100                                                           BRE04630
   ISN 0090        220 CONTINUE                                                            BRE04640
                 C                                                                         BRE04650
                 C     SAVE VERTICAL FIELD AND RETURN                                      BRE04660
                 C                                                                         BRE04670
   ISN 0091            EV = E3                                                             BRE04680
                 C     PRINT 300,EH,EV                                                     BRE04690
                 C 300 FORMAT(//5X,'***** E HORIZONTAL',G12.6,5X,'VERTICAL',G12.6//)       BRE04700
   ISN 0092            RETURN                                                              BRE04710
   ISN 0093            END                                                                 BRE04720

*OPTIONS IN EFFECT*NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(0228K) AUTODBL(NONE)

*OPTIONS IN EFFECT*SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT GOSTMT NOXREF NOALC NOANSF TERMINAL FLAG(I)

*STATISTICS*     SOURCE STATEMENTS =      92, PROGRAM SIZE =    10142, SUBPROGRAM NAME =GRNDWV

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                                    92K BYTES OF CORE NOT USED
```

```
LEVEL 2.1 ( JAN 75 )                    OS/360  FORTRAN H EXTENDED              DATE 77.271/15.31.47        PAGE   1

REQUESTED OPTIONS: ID

OPTIONS IN EFFECT: NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(0228K) AUTODBL(NONE)
                   SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT GOSTMT NOXREF NOALC NOANSF TERMINAL FLAG(I)

   ISN 0002           SUBROUTINE MOHNKL (Z,H1,H2,H1PRME,H2PRME)                        BRE04730
                C                                                                      BRE04740
                C     THIS SUBROUTINE CALCULATES THE MODIFIED HANKEL FUNCTION OF THE   BRE04750
                C     FIRST KIND AND ORDER ONE-THIRD.CONSULT REFERENCE BELOW FOR       BRE04760
                C     FURTHER INFORMATION.                                             BRE04770
                C                                                                      BRE04780
                C     REFERENCE-TABLES OF THE MODIFIED HANKEL FUNCTIONS OF ORDER ONE-  BRE04790
                C     THIRD AND OF THEIR DERIVATIVES.                                  BRE04800
                C     STAFF OF THE COMPUTATION LABORATORY AT CAMBRIDGE, MASS.          BRE04810
                C     HARVARD UNIVERSITY, 1945.                                        BRE04820
                C                                                                      BRE04830
                C                                                                      BRE04840
   ISN 0003           IMPLICIT REAL *8 (A-H,O-Z)                                       BRE04850
   ISN 0004           COMPLEX*16 Z,I,H1,H2,H1PRME,H2PRME,ZPOWER,TERM1,TERM2,           BRE04860
                     $          TERM3,ZTERM,TERM,SUM1,SUM2,SUM3,SUM4,SQRTZ8,           BRE04870
                     $          EXP1,EXP2,EXP3,EXP4,EXP5,GM2F,GPMFP,MPOWER,BETA,RTZ,   BRE04880
                     $          CONST1,CONST2,CONST3,CONST4                            BRE04890
   ISN 0005           DIMENSION A(23), B(23), C(23), D(23), CAP(14)                    BRE04900
   ISN 0006           DATA A/                                                          BRE04910
                     $   9.304367169300000D-01,3.101455723097000D 01,2.067637148731600D 02,BRE04920
                     $   5.743436524254500D 02,8.702176551900800D 02,8.287787192286400D 02,BRE04930
                     $   5.416854374043400D 02,2.579454463830200D 02,9.345849506631000D 01,BRE04940
                     $   2.662635187074000D 01,6.121000430056000D 00,1.159280384480000D 00,BRE04950
                     $   1.840127594410000D-01,2.483303096400000D-02,2.884208010000000D-03,BRE04960
                     $   2.913341420000000D-04,2.582749500000000D-05,2.025686000000000D-06,BRE04970
                     $   1.415570000000000D-07,8.870000000000000D-09,5.010000000000000D-10,BRE04980
                     $   2.600000000000000D-11,1.000000000000000D-12/                  BRE04990
   ISN 0007           DATA B/                                                          BRE05000
                     $   6.782987251400000D-01,1.130497875240000D 01,5.383323215431000D 01,BRE05010
                     $   1.196294047873500D 02,1.533710317786500D 02,1.278091931488800D 02,BRE05020
                     $   7.474221821572000D 01,3.235593862152000D 01,1.078531287384000D 01,BRE05030
                     $   2.853257374030000D 00,6.136037363510000D-01,1.093767800980000D-01,BRE05040
                     $   1.642293995500000D-02,2.105505122000000D-03,2.331677880000000D-04,BRE05050
                     $   2.252828900000000D-05,1.915671000000000D-06,1.444700000000000D-07,BRE05060
                     $   9.729000000000000D-09,5.890000000000000D-10,3.200000000000000D-11,BRE05070
                     $   2.000000000000000D-12,0.000000000000000D 00/                  BRE05080
   ISN 0008           DATA C/                                                          BRE05090
                     $   4.652183584600000D-01,6.202911446190000D 00,2.584546435915000D 01,BRE05100
                     $   5.221305931140000D 01,6.215840394215000D 01,4.875168936639000D 01,BRE05110
                     $   2.708427187022000D 01,1.121501940796000D 01,3.594557502550000D 00,BRE05120
                     $   9.181500645100000D-01,1.912812634390000D-01,3.312229669900000D-02,BRE05130
                     $   4.842441038000000D-03,6.056836820000000D-04,6.555018200000000D-05,BRE05140
                     $   6.198599000000000D-06,5.165500000000000D-07,3.822000000000000D-08,BRE05150
                     $   2.528000000000000D-09,1.500000000000000D-10,8.000000000000000D-12,BRE05160
                     $   0.000000000000000D 00,0.000000000000000D 00/                  BRE05170
   ISN 0009           DATA D/                                                          BRE05180
                     $   6.782987251400000D-01,4.521991500962000D 01,3.768326250801500D 02,BRE05190
                     $   1.196294047873500D 03,1.993823413122500D 03,2.044947090382060D 03,BRE05200
                     $   1.420102146098650D 03,7.118306496735100D 02,2.696328218460300D 02,BRE05210
                     $   7.989120647290000D 01,1.902171582688000D 01,3.718810523339000D 00,BRE05220
                     $   6.076487783230000D-01,8.422020489600000D-02,1.002621486900000D-02,BRE05230
                     $   1.036301278000000D-03,9.386786900000000D-05,7.512435000000000D-06,BRE05240
                     $   5.350740000000000D-07,3.413500000000000D-08,1.962000000000000D-09,BRE05250
```

```
                  $   1.020000000000000D-10,5.000000000000000D-12/                   BRE05260
 ISN 0010           DATA CAP/                                                        BRE05270
                  $   1.041666666666667D-01,8.355034722222222D-02,1.282265745563270-01,BRE05280
                  $   2.918490264641400-01,8.816272674437580-01,3.321408281862770 00,BRE05290
                  $   1.499576298686260 01,7.892301301158700 01,4.744515388680000 02,BRE05300
                  $   3.207490091000000 03,2.408654960000000 04,1.989231200000000 05,BRE05310
                  $   1.791902000000000 06,1.748437700000000 07/                      BRE05320
          C                                                                          BRE05330
 ISN 0011           DATA I/(0.,1.)/                                                  BRE05340
 ISN 0012           DATA ROOT3/1.73205080756888D 00/                                 BRE05350
 ISN 0013           DATA ALPHA/8.53667218838951D-01/                                 BRE05360
 ISN 0014           DATA CONST1/( 2.58819045102522D-01,-9.65925826289067D-01)/       BRE05370
 ISN 0015           DATA CONST2/( 2.58819045102522D-01, 9.65925826289067D-01)/       BRE05380
 ISN 0016           DATA CONST3/(-9.65925826289067D-01, 2.58819045102522D-01)/       BRE05390
 ISN 0017           DATA CONST4/(-9.65925826289067D-01,-2.58819045102522D-01)/       BRE05400
          C                                                                          BRE05410
 ISN 0018           ZPOWER=1.0                                                       BRE05420
 ISN 0019           SUM3=0.0                                                         BRE05430
 ISN 0020           SUM4=0.0                                                         BRE05440
 ISN 0021           ZMAG=CDABS(Z)                                                    BRE05450
 ISN 0022           IF(ZMAG .GT. 4.2) GO TO 70                                       BRE05460
 ISN 0024           IF(ZMAG .GE. 3.2) GO TO 10                                       BRE05470
 ISN 0026           N=12                                                             BRE05480
 ISN 0027           GO TO 30                                                         BRE05490
 ISN 0028   10      IF(ZMAG .GE. 4.1) GO TO 20                                       BRE05500
 ISN 0030           N=15                                                             BRE05510
 ISN 0031           GO TO 30                                                         BRE05520
 ISN 0032   20      N=23                                                             BRE05530
 ISN 0033   30      SUM1=0.                                                          BRE05540
 ISN 0034           SUM2=0.                                                          BRE05550
 ISN 0035           ZTERM=-Z**3/200.0                                                BRE05560
 ISN 0036           DO 50 M=1,N                                                      BRE05570
 ISN 0037           SUM1=SUM1+A(M)*ZPOWER                                            BRE05580
 ISN 0038           SUM2=SUM2+B(M)*ZPOWER                                            BRE05590
 ISN 0039           SUM3=SUM3+C(M)*ZPOWER                                            BRE05600
 ISN 0040           SUM4=SUM4+D(M)*ZPOWER                                            BRE05610
 ISN 0041           ZPOWER=ZPOWER*ZTERM                                              BRE05620
 ISN 0042           IF(CDABS(ZPOWER) .LE. 1.0D-30) GO TO 60                          BRE05630
 ISN 0044   50      CONTINUE                                                         BRE05640
 ISN 0045   60      GM2F=I*(Z*SUM2-2.*SUM1)/ROOT3                                    BRE05650
 ISN 0046           GPMFP=I*(SUM4+2.*Z*Z*SUM3)/ROOT3                                 BRE05660
 ISN 0047           H1=Z*SUM2+GM2F                                                   BRE05670
 ISN 0048           H2=H1-2.0*GM2F                                                   BRE05680
 ISN 0049           H1PRME=SUM4+GPMFP                                                BRE05690
 ISN 0050           H2PRME=H1PRME-2.0*GPMFP                                          BRE05700
 ISN 0051           RETURN                                                           BRE05710
          C                                                                          BRE05720
 ISN 0052   70      SUM1=1.0                                                         BRE05730
 ISN 0053           SUM2=1.0                                                         BRE05740
 ISN 0054           RTZ=CDSQRT(Z)                                                    BRE05750
 ISN 0055           SQRTZB=RTZ*Z                                                     BRE05760
 ISN 0056           ZTERM=I/SQRTZB                                                   BRE05770
 ISN 0057           MPOWER=1.0                                                       BRE05780
 ISN 0058           TERM=-1.5/Z                                                      BRE05790
 ISN 0059           DO 80 M=1,14                                                     BRE05800
 ISN 0060           ZPOWER=ZPOWER*ZTERM                                              BRE05810
 ISN 0061           MPOWER=MPOWER*(-ZTERM)                                           BRE05820
 ISN 0062           TERM1=CAP(M)*ZPOWER                                              BRE05830
```

```
ISN 0063          TERM2=CAP(M)*MPOWER                                           BRE05840
ISN 0064          SUM1=SUM1+TERM1                                               BRE05850
ISN 0065          SUM2=SUM2+TERM2                                               BRE05860
ISN 0066          SUM3=SUM3+M*TERM1                                             BRE05870
ISN 0067          SUM4=SUM4+M*TERM2                                             BRE05880
ISN 0068     80   CONTINUE                                                      BRE05890
ISN 0069          SUM3=SUM3*TERM                                                BRE05900
ISN 0070          SUM4=SUM4*TERM                                                BRE05910
ISN 0071          EXP1=CDEXP(2.*I*SQRTZB/3.)                                    BRE05920
ISN 0072          EXP2=EXP1*CONST1                                              BRE05930
ISN 0073          EXP3=CONST2/EXP1                                              BRE05940
ISN 0074          EXP4=CONST3*EXP1                                              BRE05950
ISN 0075          EXP5=CONST4/EXP1                                              BRE05960
ISN 0076          BETA=ALPHA/CDSQRT(RTZ)                                        BRE05970
ISN 0077          ZREAL=Z                                                       BRE05980
ISN 0078          ZIMAG=-I*Z                                                    BRE05990
ISN 0079          IF (ZREAL.GE.0.0.OR.ZIMAG.GE.0.0)GO TO 90                     BRE06000
ISN 0081          H1=BETA*(EXP2*SUM2+EXP5*SUM1)                                 BRE06010
ISN 0082          H1PRME=BETA*(EXP2*(SUM2*(-0.25/Z+I*RTZ)+SUM4)+EXP5*(SUM1*(-0.25/Z BRE06020
                 $       -I*RTZ)+SUM3))                                         BRE06030
ISN 0083          GO TO 110                                                     BRE06040
ISN 0084     90   H1=BETA*EXP2*SUM2                                             BRE06050
ISN 0085          H1PRME=BETA*EXP2*(SUM2*(-0.25/Z+I*RTZ)+SUM4)                  BRE06060
ISN 0086    110   IF (ZREAL.GE.0.0.OR.ZIMAG.LT.0.0)GO TO 120                    BRE06070
ISN 0088          H2=BETA*(EXP3*SUM1+EXP4*SUM2)                                 BRE06080
ISN 0089          H2PRME=BETA*(EXP3*(SUM1*(-0.25/Z-I*RTZ)+SUM3)+EXP4*(SUM2*(-0.25/Z BRE06090
                 $       +I*RTZ)+SUM4))                                         BRE06100
ISN 0090          RETURN                                                        BRE06110
ISN 0091    120   H2=BETA*EXP3*SUM1                                             BRE06120
ISN 0092          H2PRME=BETA*EXP3*(SUM1*(-0.25/Z-I*RTZ)+SUM3)                  BRE06130
ISN 0093          RETURN                                                        BRE06140
ISN 0094          END                                                           BRE06150

*OPTIONS IN EFFECT*NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(0228K) AUTODBL(NONE)

*OPTIONS IN EFFECT*SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT GOSTMT NOXREF NOALC NOANSF TERMINAL FLAG(I)

*STATISTICS*     SOURCE STATEMENTS =      93, PROGRAM SIZE =     6642, SUBPROGRAM NAME =MDHNKL

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                              96K BYTES OF CORE NOT USED
```

```
LEVEL 2.1  ( JAN 75 )                    OS/360  FORTRAN H EXTENDED              DATE 77.271/15.32.11        PAGE    1

REQUESTED OPTIONS: ID

OPTIONS IN EFFECT: NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(0228K) AUTODBL(NONE)
                   SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT GOSTMT NOXREF NOALC NOANSF TERMINAL FLAG(I)

   ISN 0002          SUBROUTINE ASGEPS(SEGSIZ,ISGCNT,XLOC,YLOC,DIR,WVEL,SOUT,EOUT)       BRE06160
   ISN 0003          COMMON ERTHR,PI,RAD,DEG,PIBY2,TWOPI,REFIND,FREQ                     BRE06170
   ISN 0004          COMMON /BON/ LONG,LAT,GAMMA,GMT,IO                                  BRE06180
   ISN 0005          REAL LONG, LAT                                                      BRE06190
   ISN 0006          EPSLON = 0.                                                         BRE06200
   ISN 0007          SIGMA = 0.                                                          BRE06210
   ISN 0008          PTHDST = 0.                                                         BRE06220
   ISN 0009          DLAT = XLOC                                                         BRE06230
   ISN 0010          DLONG = YLOC                                                        BRE06240
   ISN 0011          DO 100 KCNT = 1, ISGCNT                                             BRE06250
   ISN 0012          LAT = DLAT*RAD                                                      BRE06260
   ISN 0013          LONG = DLONG*RAD                                                    BRE06270
   ISN 0014          CALL NWOMAP                                                         BRE06280
   ISN 0015          CALL ESGEPS(GAMMA,XSIG,XEPS,WVEL)                                   BRE06290
   ISN 0016          PRINT 115,DLAT,DLONG,XSIG,XEPS                                      BRE06300
   ISN 0017          SIGMA = SIGMA + XSIG                                                BRE06310
   ISN 0018          EPSLON = EPSLON + XEPS                                              BRE06320
   ISN 0019          PTHDST = PTHDST + SEGSIZ                                            BRE06330
   ISN 0020          CALL COOR(XLOC,YLOC,DIR,PTHDST,DLAT,DLONG)                          BRE06340
   ISN 0021      100 CONTINUE                                                            BRE06350
   ISN 0022          SOUT = SIGMA/ISGCNT                                                 BRE06360
   ISN 0023          EOUT = EPSLON/ISGCNT                                                BRE06370
   ISN 0024          DLAT = 99999.9999                                                   BRE06380
   ISN 0025          DLONG = DLAT                                                        BRE06390
   ISN 0026          PRINT 115,DLAT,DLONG,SOUT,EOUT                                      BRE06400
   ISN 0027      115 FORMAT(15X,4(5X,F10.4))                                             BRE06410
   ISN 0028          RETURN                                                              BRE06420
   ISN 0029          END                                                                 BRE06430

*OPTIONS IN EFFECT*NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(0228K) AUTODBL(NONE)

*OPTIONS IN EFFECT*SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT GOSTMT NOXREF NOALC NOANSF TERMINAL FLAG(I)

*STATISTICS*     SOURCE STATEMENTS =      28, PROGRAM SIZE =      878, SUBPROGRAM NAME =ASGEPS

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                                   124K BYTES OF CORE NOT USED
```

```
LEVEL 2.1  ( JAN 75 )                    OS/360  FORTRAN H EXTENDED           DATE 77.271/15.32.19        PAGE    1

REQUESTED OPTIONS: ID

OPTIONS IN EFFECT: NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(0228K) AUTODBL(NONE)
                   SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT GOSTMT NOXREF NOALC NOANSF TERMINAL FLAG(I)

  ISN 0002           SUBROUTINE FSGEPS(GAMMA,SIGMA,EPSLON,WNDVEL)                        BRE06440
  ISN 0003           IF(GAMMA.LT.0.25) GO TO 15                                          BRE06450
  ISN 0005           IF(GAMMA.GT.0.75) GAMMA = 0.75                                      BRE06460
  ISN 0007           SIGMA = 7.4995 - 9.998*GAMMA                                        BRE06470
  ISN 0008           EPSLON = 118 - 152*GAMMA                                            BRE06480
  ISN 0009           GO TO 20                                                            BRE06490
  ISN 0010        15 IF(GAMMA.GE.-0.25) GAMMA = -0.25                                    BRE06500
  ISN 0012           IF(GAMMA.LE.-0.75) GAMMA = -0.75                                    BRE06510
  ISN 0014           SIGMA = 7.49995 + 9.9998*GAMMA                                      BRE06520
  ISN 0015           EPSLON = 118 + 152*GAMMA                                            BRE06530
  ISN 0016        20 CONTINUE                                                            BRE06540
  ISN 0017           IF(SIGMA.GT.2.0) GO TO 25                                           BRE06550
  ISN 0019           RETURN                                                              BRE06560
  ISN 0020        25 CONTINUE                                                            BRE06570
  ISN 0021           BETA = 2.635E-03 + WNDVEL*8.784E-05                                 BRE06580
  ISN 0022           SIGMA = 2.778E-05/(BETA**2)                                         BRE06590
  ISN 0023           RETURN                                                              BRE06600
  ISN 0024            END                                                                BRE06610

*OPTIONS IN EFFECT*NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(0228K) AUTODBL(NONE)

*OPTIONS IN EFFECT*SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT GOSTMT NOXREF NOALC NOANSF TERMINAL FLAG(I)

*STATISTICS*     SOURCE STATEMENTS =      23, PROGRAM SIZE =      600, SUBPROGRAM NAME =FSGEPS

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                                    124K BYTES OF CORE NOT USED
```

```
REQUESTED OPTIONS: ID

OPTIONS IN EFFECT: NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(0228K) AUTODBL(NONE)
                   SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT GOSTMT NOXREF NOALC NOANSF TERMINAL FLAG(I)

  ISN 0002            SUBROUTINE CPOWER(P,TP,ALPSUM)                                    BRE06630
                C...CALCULATES TOTAL RECEIVED COMPENSATED POWER(BOTH POLAR.)            BRE06640
                C...AND ALL MODE POWER SUM                                              BRE06650
  ISN 0003            COMMON T,FACHNZ,FR,DT,DR,RHT,VNOIZ,THT                            BRE06660
  ISN 0004            COMMON /SWITCH/ KSW1,KSW2,JF,IBETA                                BRE06670
  ISN 0005            COMMON /SAVSIG/ HIRAYP                                            BRE06680
  ISN 0006            COMMON /ANTDAT/TABL1V(181,8),TABL1H(181,8),TABL2V(181,8),         BRE06690
                     *     TABL2H(181,8),OFFSET                                         BRE06700
  ISN 0007            COMMON /SPPASS/ IANT,ANTFIL,VGTOT,RGTOT,HGTOT                     BRE06710
  ISN 0008            DATA CRIT/-1.0E74/,DOUT/3HDIR/,ROUT/4HREFL/                       BRE06720
  ISN 0009            DIMENSION PVAL(4)                                                 BRE06730
  ISN 0010            EQUIVALENCE (PVAL(1),CRPREV), (PVAL(2),CRPREH), (PVAL(3),CRPDRV), BRE06740
                     $   (PVAL(4),CRPDRH)                                               BRE06750
  ISN 0011            DATA CRPDRV, CRPDRH, CRPREV, CRPREH /4*-1.0E75/                   BRE06760
  ISN 0012            REAL HNOIZ                                                        BRE06770
                C...INPUT DATA FROM FILE JF                                             BRE06780
                C...DBV,DBH,DBL=UNCOMPENSATED POWER FOR VERTICAL AND HORIZONTAL         BRE06790
                C  POLARIZATION(REFLECTED OR GROUND), BOTH POLARIZATIONS(LINE OF SIGHT) BRE06800
                C...TBD,RBD=RAY ANGLE OF DIRECT OR GROUNDWAVE(TRANS,REC)                BRE06810
                C...TBR,RBR=RAY ANGLE OF REFLECTED(TRANS,REC)                           BRE06820
  ISN 0013            READ(JF,910) KSW,DBV,DBH,DBL,TBD,TBR,RBD,RBR                      BRE06830
  ISN 0014        910 FORMAT(A1,3G12.6,4F10.3)                                          BRE06840
  ISN 0015            PRINT 911                                                         BRE06850
  ISN 0016            PRINT 912,KSW,DBV,DBH,DBL,TBD,TBR,RBD,RBR                         BRE06860
  ISN 0017        911 FORMAT(3X,3HKSW,6X,3HDBV,11X,3HDBH,11X,3HDBL,                     BRE06870
                     *11X,3HTBD,11X,3HTBR,11X,3HRBD,11X,3HRBR)                          BRE06880
  ISN 0018        912 FORMAT(4X,A1,1X,7(1X,G13.6))                                      BRE06890
                C...DIRECT RAY CALCULATIONS (IF DBL .GT. CRIT)                          BRE06900
                C   #####     DEBUG                                                     BRE06910
                C                                                                       BRE06920
  ISN 0019            PRINT 950                                                         BRE06930
  ISN 0020        950 FORMAT(//8X,'DB FROM BREM',12X,'P',12X,'TRANSMITTER GN ',6X,      BRE06940
                     $   'RECEIVER GAIN',4X,'COMPENSATED POWER'//)                      BRE06950
  ISN 0021        951 FORMAT(5(5X,F15.7))                                               BRE06960
  ISN 0022            IF(DBL.LE.CRIT)GO TO 10                                           BRE06970
                C...CALCULATE GAINS AND COMPENSATED RECEIVED POWER                      BRE06980
  ISN 0024            GDIRTV= 10.0*ALOG10(F1(TBD,TABL1V,1))                             BRE06990
  ISN 0025            GDIRRV= 10.0*ALOG10(F1(RBD,TABL2V,2))                             BRE07000
  ISN 0026            CRPDRV=DBL+P+GDIRTV+GDIRRV                                        BRE07010
  ISN 0027            PRINT 951, DBL, P, GDIRTV, GDIRRV, CRPDRV                         BRE07020
  ISN 0028            GDIRTH= 10.0*ALOG10(F1(TBD,TABL1H,1))                             BRE07030
  ISN 0029            GDIRRH= 10.0*ALOG10(F1(RBD,TABL2H,2))                             BRE07040
  ISN 0030            CRPDRH=DBL+P+GDIRTH+GDIRRH                                        BRE07050
  ISN 0031            PRINT 951, DBL, P, GDIRTH, GDIRRH, CRPDRH                         BRE07060
  ISN 0032         10 CONTINUE                                                          BRE07070
                C...REFLECTED RAY OR GROUND WAVE CALCULATIONS (IF DBV.GT.CRIT)          BRE07080
  ISN 0033            IF(DBV.LE.CRIT)GO TO 20                                           BRE07090
                C...CALCULATE GAINS AND COMPENSATION                                    BRE07100
  ISN 0035            GTV= 10.0*ALOG10(F1(TBR,TABL1V,1))                                BRE07110
  ISN 0036            GRV= 10.0*ALOG10(F1(RBR,TABL2V,2))                                BRE07120
  ISN 0037            CRPREV=DBV+P+GTV+GRV                                              BRE07130
  ISN 0038            PRINT 951, DBV, P, GTV, GRV, CRPREV                               BRE07140
  ISN 0039         20 CONTINUE                                                          BRE07150
```

```
           C...REFLECTED RAY OR GROUND WAVE CALCULATIONS (IF DBH.GT.CRIT)           BRE07160
 ISN 0040        IF(DBH.LE.CRIT)GO TO 30                                            BRE07170
           C...CALCULATE GAINS AND COMPENSATION                                     BRE07180
 ISN 0042        GTH= 10.0*ALOG10(F1(TBR,TABL1H,1))                                 BRE07190
 ISN 0043        GRH= 10.0*ALOG10(F1(RBR,TABL2H,2))                                 BRE07200
 ISN 0044        CRPREH=DBH+P+GTH+GRH                                               BRE07210
 ISN 0045        PRINT 951, DBH, P, GTH, GRH, CRPREH                                BRE07220
 ISN 0046     30 CONTINUE                                                           BRE07230
           C                                                                        BRE07240
           C       SET UP FOR COMPUTATION OF TOTAL COMPENSATED POWER BY             BRE07250
           C        ADDITION OF COMPONENTS NOT MORE THAN 100 DB DOWN FROM           BRE07260
           C        MOST SIGNIFICANT COMPONENT                                      BRE07270
           C                                                                        BRE07280
 ISN 0047        PLARGE = -1.0E75                                                   BRE07290
 ISN 0048        PSMALL = 1.0E75                                                    BRE07300
 ISN 0049        DO 50 I = 1,4                                                      BRE07310
 ISN 0050        IF(PVAL(I).GT.PLARGE) PLARGE = PVAL(I)                             BRE07320
 ISN 0052        IF(PVAL(I).LT.PSMALL) PSMALL = PVAL(I)                             BRE07330
 ISN 0054     50 CONTINUE                                                           BRE07340
 ISN 0055        DIF = PLARGE - PSMALL                                              BRE07350
 ISN 0056        IF(DIF.LE.100.00) GO TO 55                                         BRE07360
 ISN 0058        PSMALL = PLARGE - 100.00                                           BRE07370
 ISN 0059     55 CONTINUE                                                           BRE07380
           C                                                                        BRE07390
           C     RESET ORIGIN TO PREVENT OVERFLOW/UNDERFLOW                         BRE07400
           C                                                                        BRE07410
 ISN 0060        LBASE = PSMALL                                                     BRE07420
 ISN 0061        TPCOMP = 0.00                                                      BRE07430
 ISN 0062        DO 100 I = 1,4                                                     BRE07440
 ISN 0063        IF(PVAL(I).LT.PSMALL) GO TO 100                                    BRE07450
 ISN 0065        DIF = PVAL(I) - LBASE                                              BRE07460
           C                                                                        BRE07470
           C   DEBUG                                                                BRE07480
           C     PRINT 94, I, PVAL(I), DIF                                          BRE07490
           C  94 FORMAT(/'*****     PVAL',I2,2X,G15.6,'   USING DIF = ',G15.6)      BRE07500
           C                                                                        BRE07510
           C     CONVERT DB TO POWER AND ADD                                        BRE07520
           C                                                                        BRE07530
 ISN 0066        TPCOMP = TPCOMP + 10.00**(DIF/10.00)                               BRE07540
           C     PRINT 966, TPCOMP                                                  BRE07550
           C 966 FORMAT(//10X,'*****      TPCOMP NOW = ',G15.6//)                   BRE07560
 ISN 0067    100 CONTINUE                                                           BRE07570
           C                                                                        BRE07580
           C     CONVERT POWER TO DB AND CORRECT ORIGIN FOR TOTAL POWER             BRE07590
           C                                                                        BRE07600
 ISN 0068        TP = LBASE + 10.00*ALOG10(TPCOMP)                                  BRE07610
           C  .....     CALCULATE ALL MODE POWER SUM .....                          BRE07620
 ISN 0069        IF(HIRAYP.GT.TP) GO TO 120                                         BRE07630
 ISN 0071        DIF = TP - HIRAYP                                                  BRE07640
 ISN 0072        IF(DIF.LE.100.00) GO TO 110                                        BRE07650
 ISN 0074        ALPSUM = TP                                                        BRE07660
 ISN 0075        GO TO 150                                                          BRE07670
 ISN 0076    110 CONTINUE                                                           BRE07680
 ISN 0077        LBASE = HIRAYP                                                     BRE07690
 ISN 0078        GO TO 140                                                          BRE07700
 ISN 0079    120 CONTINUE                                                           BRE07710
 ISN 0080        DIF = HIRAYP - TP                                                  BRE07720
 ISN 0081        IF(DIF.LE.100.00) GO TO 130                                        BRE07730
```

```
ISN 0083            ALPSUM = HIRAYP                                                  BRE07740
ISN 0084            GO TO 150                                                        BRE07750
ISN 0085        130 CONTINUE                                                         BRE07760
ISN 0086            LBASE = TP                                                       BRE07770
ISN 0087        140 CONTINUE                                                         BRE07780
ISN 0088            TPCOMP = 10.00**((TP - LBASE)/10.00)                             BRE07790
ISN 0089            TPCOMP = TPCOMP + 10.00**((HIRAYP - LBASE)/10.00)                BRE07800
ISN 0090            ALPSUM = 10.00*ALOG10(TPCOMP) + LBASE                            BRE07810
ISN 0091        150 CONTINUE                                                         BRE07820
              C                                                                      BRE07830
              C   CALCULATE CORRECTED NOISE POWER AND S/N RATIO                      BRE07840
              C                                                                      BRE07850
ISN 0092            CONHNZ = (1.00 - EXP( -FACHNZ*PHT))*(HGTOT/RGTOT)                BRE07860
ISN 0093            CONVNZ = VGTOT/RGTOT                                             BRE07870
              C                                                                      BRE07880
              C   DEBUG OUTPUT .....                                                 BRE07890
              C                                                                      BRE07900
              C     PRINT 924, HGTOT,VGTOT,RGTOT,CONHNZ,CONVNZ                       BRE07910
ISN 0094            TNOIZ = VNOIZ + 10.0*ALOG10(CONVNZ + CONHNZ)                     BRE07920
ISN 0095            CTDSNR = ALPSUM + TNOIZ                                          BRE07930
ISN 0096            PRINT 925                                                        BRE07940
ISN 0097            PRINT 930,(PVAL(I),I = 1,4),HIRAYP,VNOIZ,TNOIZ,CTDSNR            BRE07950
ISN 0098            PRINT 945                                                        BRE07960
ISN 0099            PRINT 902                                                        BRE07970
ISN 0100            RETURN                                                           BRE07980
ISN 0101        902 FORMAT (1H ,7X,3HGMT,3X,4HTIME,3X,4HFREQ,3X,6HNMODES,4X,3HMGT,   BRE07990
                  * 8X,7H2*SIGMA,8X,6HSIGNAL,9X,3HS/N,11X,5HEFPL ,8X,8H(S/N)MAX /    BRE08000
                  * 1H ,13X,5H(SEC),19X,4H(MS),8X,4H(MS),10X,6H(-DBW),9X,4H(DB),     BRE08010
                  * 10X,4H(DB),10X,4H(DB) //)                                        BRE08020
ISN 0102        924 FORMAT(//10X,'DEBUG',10(4H****),/20X,                            BRE08030
                  1    '  HGTOT         VGTOT         RGTOT         CONHNZ        CONVNZ',BRE08040
                  2    /20X,5(G10.5,3X),//15X,10(4H****))                            BRE08050
ISN 0103        925 FORMAT( /35X,15(4H****),//45X,'SIGNAL ANALYSIS INCLUDING BREM ', BRE08060
                  1    'ANALYSIS',//10X,'GROUND OR REFLECTED',18X,'DIRECT',14X,      BRE08070
                  2    'IONOSPHERIC',5X,'VERTICAL',7X,'CORRECTED',6X,'CORRECTED',/8X, BRE08080
                  3    2(1X,'VERTICAL',6X,'HORIZONTAL',5X),'SIGNAL SUM',7X,'NOISE',  BRE08090
                  4    10X,'NOISE',8X,'ALL MODE',/5X,5(6X,'DBW',6X),2(5X,'-DBW',6X), BRE08100
                  5    3X,'S/N RATIO',//)                                            BRE08110
ISN 0104        930 FORMAT(9X,8(G12.6,3X)/)                                          BRE08120
ISN 0105        945 FORMAT(5X,30(4H****)//)                                          BRE08130
ISN 0106            END                                                              BRE08140
```

```
NUMBER   LEVEL                        FORTRAN H EXTENDED ERROR MESSAGES

IFE307I   4(W)      NAME 88DOUT       THE DATA STATEMENT CONTAINS A VARIABLE THAT IS NOT REFERENCED.
IFE307I   4(W)      NAME 88BOUT       THE DATA STATEMENT CONTAINS A VARIABLE THAT IS NOT REFERENCED.

*OPTIONS IN EFFECT*NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(0228K) AUTODBL(NONE)

*OPTIONS IN EFFECT*SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT GOSTMT NOXREF NOALC NOANSF TERMINAL FLAG(I)

*STATISTICS*     SOURCE STATEMENTS =     105, PROGRAM SIZE =     3474, SUBPROGRAM NAME =CPOWER

*STATISTICS*    2 DIAGNOSTICS GENERATED, HIGHEST SEVERITY CODE IS  4

****** END OF COMPILATION ******                                 108K BYTES OF CORE NOT USED
```

```
LEVEL 2.1  ( JAN 75 )                    OS/360  FORTRAN H EXTENDED              DATE 77.271/15.32.49         PAGE   1

REQUESTED OPTIONS: ID

OPTIONS IN EFFECT: NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(0228K) AUTODBL(NONE)
                   SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT GOSTMT NOXREF NOALC NOANSF TERMINAL FLAG(I)

  ISN 0002            FUNCTION F1(X,TABL,NPAT)                                           BRE08150
                C                                                                        BRE08160
                C        CALIBRATE THE ANTENNA.  IF THE ANTENNA CALIBRATION TABLES ARE   BRE08170
                C        NOT READ IN, SENSE SWITCH 1 IS ON AND THE ANTENNA GAIN WITH     BRE08180
                C        RESPECT TO ISOTROPIC IS SET TO 1.                               BRE08190
                C                                                                        BRE08200
                C                                                                        BRE08210
                C          VARIABLES WHICH ARE READ IN FROM CARDS                        BRE08220
                C                                                                        BRE08230
  ISN 0003            COMMON T,M,FR,DT,DR,PL,N,PT1,TAU(60),GMT,BAUD,P                    BRE08240
                C                                                                        BRE08250
                C          VARIABLES WHICH ARE COMPUTED                                  BRE08260
                C                                                                        BRE08270
  ISN 0004            COMMON LIMIT,NTIME,NFREQ,OLDT,OLDFR,OLDGMT,S1,S2,K,N1,NCDS         BRE08280
                C                                                                        BRE08290
                C          VARIABLE ARRAYS                                               BRE08300
                C                                                                        BRE08310
  ISN 0005            COMMON PT(1000,3),A(1000),PHASET(1000),TAUS(1000),                 BRE08320
                     *       MODE(60),TIME(30),FREQ(30),                                 BRE08330
                     *       SIGTAU(20,20),SIGNOI (20,20)                                BRE08340
  ISN 0006            COMMON /ANTDAT/ TABL1V(181,8),TABL1H(181,8),TABL2V(181,8),         BRE08350
                     *TABL2H(181,8),MXANGL(2),MNANGL(2),KRXN(2),NANGLS(2)                BRE08360
  ISN 0007            COMMON /SPPASS/NUMF                                                BRE08370
  ISN 0008            COMMON/SWITCH/KSW1,KSW2,JF,IBETA                                   BRE08380
  ISN 0009            INTEGER*4 GMT, OLDGMT, OFFSET                                      BRE08390
  ISN 0010            REAL N, MODE,M                                                     BRE08400
  ISN 0011            DIMENSION TABL(181,8)                                              BRE08410
  ISN 0012            COMMON /DATA/ C2, FOURPI,  EFPL, TABLFR(15), ISW, MX1, IDEBUG      BRE08420
  ISN 0013            DATA MESPRT /0/                                                    BRE08430
  ISN 0014            NAMELIST /INTRPL/ IANGL,KANGL,DELNGL,DELFR,G1,G2,F1                BRE08440
                C                                                                        BRE08450
                C   IF ANTENNA CALIBRATION TABLES WERE NOT READ IN USE ISOTROPIC 1.00    BRE08460
                C                                                                        BRE08470
  ISN 0015            IF(KSW1.EQ.0) GO TO 100                                            BRE08480
  ISN 0017            IF(MESPRT.GT.0) GO TO 50                                           BRE08490
  ISN 0019            MESPRT = 1                                                         BRE08500
  ISN 0020            PRINT 905                                                          BRE08510
  ISN 0021         50 CONTINUE                                                           BRE08520
  ISN 0022            F1 = 1.00                                                          BRE08530
  ISN 0023            RETURN                                                             BRE08540
  ISN 0024        100 CONTINUE                                                           BRE08550
  ISN 0025            LFR = 1                                                            BRE08560
  ISN 0026            IFR = 1                                                            BRE08570
  ISN 0027            DELFR = 0.00                                                       BRE08580
                C    FIRST CASE ONLY ONE FREQUENCY PROVIDED --                           BRE08590
                C      NO INTERPOLATION ON FREQUENCY                                     BRE08600
                C                                                                        BRE08610
  ISN 0028            IF(NUMF.EQ.1) GO TO 200                                            BRE08620
                C                                                                        BRE08630
                C   IF FREQUENCY IS OUT OF RANGE USE ISOTROPIC WITH WARNING              BRE08640
                C                                                                        BRE08650
  ISN 0030            IF(FR.LT.TABLFR(1).OR.FR.GT.TABLFR(NUMF)) GO TO 500                BRE08660
                C                                                                        BRE08670
```

```
              C    OTHERWISE BRACKET FREQUENCY AND DETERMINE DELTA (DELFR)              BRE08680
              C                                                                         BRE08690
ISN 0032             DO 150 I = 2,NUMF                                                  BRE08700
ISN 0033             IFR = I                                                            BRE08710
ISN 0034             IF(FR.LE.TABLFR(IFR)) GO TO 160                                    BRE08720
ISN 0036         150 CONTINUE                                                           BRE08730
ISN 0037         160 CONTINUE                                                           BRE08740
ISN 0038             LFR = IFR - 1                                                      BRE08750
ISN 0039             DELFR = (FR - TABLFR(LFR))/(TABLFR(IFR) - TABLFR(LFR))             BRE08760
ISN 0040         200 CONTINUE                                                           BRE08770
              C                                                                         BRE08780
              C    OTHERWISE DETERMINE DELTA                                            BRE08790
              C                                                                         BRE08800
ISN 0041             IANGL = X                                                          BRE08810
              C                                                                         BRE08820
              C      IF X IS LESS THAN ZERO CORRECT IANGLE TO FIT                       BRE08830
              C         INTERPOLATION ASSUMPTIONS.....                                  BRE08840
              C                                                                         BRE08850
ISN 0042             IF(X.LT.0.00) IANGL = IANGL - 1                                    BRE08860
ISN 0044             DELNGL = X - IANGL                                                 BRE08870
              C                                                                         BRE08880
              C    ADJUST IANGL SO THAT IT POINTS TO CORRECT ROW IN GAIN TABLE.         BRE08890
              C                                                                         BRE08900
ISN 0045             MINANG = MNANGL(NPAT)                                              BRE08910
ISN 0046             MAXANG = MXANGL(NPAT)                                              BRE08920
ISN 0047             NUMANG = NANGLS(NPAT)                                              BRE08930
ISN 0048             IANGL = IANGL + KRXN(NPAT)                                         BRE08940
ISN 0049             KANGL = IANGL + 1                                                  BRE08950
              C                                                                         BRE08960
              C    IF ANGLE IS OUT OF RANGE USE ISOTROPIC WITH WARNING                  BRE08970
              C                                                                         BRE08980
ISN 0050             IF(IANGL.GT.NUMANG.OR.IANGL.LT.1) GO TO 520                        BRE08990
              C                                                                         BRE09000
              C  IF IANGLE IS OK BUT KANGL IS TOO LARGE, F1 = G1                        BRE09010
              C                                                                         BRE09020
ISN 0052             IF(KANGL.LE.NUMANG) GO TO 240                                      BRE09030
ISN 0054             DELNGL  = 0.00                                                     BRE09040
ISN 0055             G2 = 1000000.                                                      BRE09050
ISN 0056             GO TO 250                                                          BRE09060
ISN 0057         240 CONTINUE                                                           BRE09070
              C                                                                         BRE09080
              C    BRACKET GAIN                                                         BRE09090
              C                                                                         BRE09100
ISN 0058             G2 = TABL(KANGL,LFR) + DELFR*(TABL(KANGL,IFR) - TABL(KANGL,LFR))   BRE09110
ISN 0059         250 CONTINUE                                                           BRE09120
ISN 0060             G1 = TABL(IANGL,LFR) + DELFR*(TABL(IANGL,IFR) - TABL(IANGL,LFR))   BRE09130
ISN 0061             F1 = G1 + DELNGL*(G2 - G1)                                         BRE09140
ISN 0062             IF(IDEBUG.GT.5) WRITE(6,INTRPL)                                    BRE09150
ISN 0064             RETURN                                                             BRE09160
              C                                                                         BRE09170
              C    ERROR HANDLING                                                       BRE09180
              C                                                                         BRE09190
ISN 0065         500 CONTINUE                                                           BRE09200
ISN 0066             PRINT 901, FR, TABLFR(1), TABLFR(NUMF)                             BRE09210
ISN 0067              GO TO 550                                                         BRE09220
ISN 0068         520 CONTINUE                                                           BRE09230
ISN 0069             PRINT 902, X, MAXANG, MINANG                                       BRE09240
ISN 0070         550 CONTINUE                                                           BRE09250
```

```
  ISN 0071          PRINT 905                                                  BRE09260
  ISN 0072          F1 = 1.00                                                  BRE09270
  ISN 0073          RETURN                                                     BRE09280
  ISN 0074      901 FORMAT(//5X,'*****     FREQUENCY',F10.5,                   BRE09290
               $    '  OUT OF SPECIFIED RANGE:',F10.5,' TO',F10.5)             BRE09300
  ISN 0075      902 FORMAT(//5X,'*****     ANGLE',F10.5,'  OUT OF SPECIFIED RANGE:',  BRE09310
               $    I5,'  --  ',I5)                                            BRE09320
  ISN 0076      905 FORMAT(/10X,'*****     ANTENNA CALIBRATION TABLES NOT USED  *'/)  BRE09330
  ISN 0077          END                                                        BRE09340

*OPTIONS IN EFFECT*NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(0228K) AUTODBL(NONE)

*OPTIONS IN EFFECT*SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT GOSTMT NOXREF NOALC NOANSF TERMINAL FLAG(I)

*STATISTICS*     SOURCE STATEMENTS =      76, PROGRAM SIZE =     1814, SUBPROGRAM NAME =@@@@F1

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                                 116K BYTES OF CORE NOT USED
```

```
REQUESTED OPTIONS: ID

OPTIONS IN EFFECT: NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(0228K) AUTODBL(NONE)
                   SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT GOSTMT NOXREF NOALC NOANSF TERMINAL FLAG(I)

  ISN 0002          SUBROUTINE INITLC                                                     BRE09350
            C                                                                             BRE09360
            C          INITIALIZES COUNTERS AND ARRAYS, PRINTS THE IDENTIFICATION         BRE09370
            C          CARD AND READS THE ANTENNA CALIBRATION TABLES WHEN THEY ARE        BRE09380
            C          PROVIDED.                                                          BRE09390
            C                                                                             BRE09400
            C           DECLARATION STATEMENTS                                            BRE09410
            C                                                                             BRE09420
            C           VARIABLES WHICH ARE READ IN FROM CARDS                            BRE09430
            C                                                                             BRE09440
  ISN 0003          COMMON T,M,FR,DT,DR,PL,N,PT1,TAU(60),GMT,BAUD,P                       BRE09450
            C                                                                             BRE09460
            C                                                                             BRE09470
            C           VARIABLES WHICH ARE COMPUTED                                      BRE09480
            C                                                                             BRE09490
  ISN 0004          COMMON LIMIT,NTIME,NFREQ,OLDT,OLDFR,OLDGMT,S1,S2,K,N1,NCDS            BRE09500
            C           VARIABLE ARRAYS                                                   BRE09510
            C                                                                             BRE09520
  ISN 0005          COMMON PT(1000,3),A(1000),PHASET(1000),TAUS(1000),                    BRE09530
                  *         MODE(60),TIME(30),FREQ(30),                                   BRE09540
                  *         SIGTAU(20,20),SIGNOI (20,20)                                  BRE09550
  ISN 0006          COMMON /ANTDAT/ TABL1V(181,8),TABL1H(181,8),TABL2V(181,8),            BRE09560
                  *TABL2H(181,8), MXANGL(2),MNANGL(2),KRXN(2),NANGLS(2)                   BRE09570
  ISN 0007          COMMON /CONTRO /  PLREJ                                               BRE09580
  ISN 0008          COMMON /DATA/ C2, FOURPI,  EFPL, TABLFR(15), ISW, MX1, IDEBUG         BRE09590
  ISN 0009          COMMON/SWITCH/KSW1,KSW2,JF,IBETA,JCARD,NEWANT                         BRE09600
  ISN 0010          COMMON /SPPASS/ NOFREQ,ANTFIL,VGTOT,RGTOT,HGTOT                       BRE09610
  ISN 0011          NAMELIST /IINIT/ NOFREQ,KSW1,KSW2,JCARD,NEWANT,MXANGT,MXANGR,         BRE09620
                  1    ANTFIL,P,BAUD,PLREJ,IBETA,MNANGT,MNANGR,IDEBUG                     BRE09630
  ISN 0012          DATA BLNK/1H /, NCALLS /0/                                            BRE09640
  ISN 0013          DIMENSION HEADER(7)                                                   BRE09650
  ISN 0014          EQUIVALENCE (MXANGL(1),MXANGT),(MXANGL(2),MXANGR),                    BRE09660
                  1    (MNANGL(1),MNANGT),(MNANGL(2),MNANGR)                              BRE09670
  ISN 0015          REAL*8 HEADER                                                         BRE09680
  ISN 0016          INTEGER*4 OLDGMT,GMT,ANTFIL                                           BRE09690
  ISN 0017          REAL N                                                                BRE09700
  ISN 0018          REAL MODE,M                                                           BRE09710
  ISN 0019          ENTRY INITIA                                                          BRE09720
  ISN 0020          FR = 1.0                                                              BRE09730
  ISN 0021          P = 3.333                                                             BRE09740
  ISN 0022          BAUD = 0.01                                                           BRE09750
  ISN 0023          PLREJ = 0.0                                                           BRE09760
  ISN 0024          ISW=1                                                                 BRE09770
  ISN 0025        4 DO 5 I = 1, 20                                                        BRE09780
  ISN 0026          DO 5 J = 1, 20                                                        BRE09790
  ISN 0027          SIGNOI (I,J) = 0.0                                                    BRE09800
  ISN 0028          SIGTAU(I,J) = 99999.0                                                 BRE09810
  ISN 0029        5 CONTINUE                                                              BRE09820
            C                                                                             BRE09830
            C          IF INPUT POWER AND/OR BAUD LENGTH ARE LESS THAN OR EQUAL TO 0      BRE09840
            C          ON INPUT CARD, SET POWER TO 3.333 AND/OR BAUD LENGTH TO 0.01.      BRE09850
            C          THESE VALUES DO NOT CHANGE UNTIL RESET BY AN INPUT CARD.           BRE09860
            C                                                                             BRE09870
```

```
ISN 0030          READ(5,IINIT)
ISN 0031          WRITE(6,IINIT)
ISN 0032          IF(NOFREQ.GT.8)NOFREQ=8
ISN 0034          IF(NOFREQ.LE.0)NOFREQ=1
ISN 0036          IF(JCARD.EQ.1)JF=5
            C
            C   IF KSW1 IS NOT EQUAL TO 0 ANTENNA PATTERNS ARE NOT USED
            C     WHEN KSW1 IS 0
            C       AND NEWANT IS GREATER THAN 0 A NEW ANTENNA PATTERN IS TO BE READ
            C     WHEN KSW1 IS 0
            C       AND NEWANT IS 0 THE LAST ANTENNA PATTERN READ IS TO BE REUSED
            C          UNLESS NCALLS IS 0 INDICATING THAT NO ANTENNA PATTERN WAS
            C            PREVIOUSLY READ .  THEN ANTENNA PATTERNS WILL NOT BE USED.
            C
ISN 0038        6 IF(KSW1 .NE. 0) GO TO 65
ISN 0040          IF(NEWANT.GT.0) GO TO 60
ISN 0042          IF(NCALLS.GT.0) GO TO 65
ISN 0044          KSW1 = 1
ISN 0045          PRINT 935
ISN 0046          GO TO 65
ISN 0047       60 CONTINUE
ISN 0048          NCALLS = NCALLS + 1
            C
            C   ENTER TRANSMITTER AND RECEIVER ANTENNA GAIN PATTERNS USING
            C      SURROUTINE RDATNA
            C
            C   ANTFIL IS A NEW VARIABLE TO ALLOW READING OF PATTERNS FROM DISK OR
            C     TAPE FILES AS WELL AS CARD DECKS.  5 SPACES HAVE BEEN TAKEN
            C     FROM THE FRONT OF KSW1.  IF ANTFIL IS LEFT BLANK OR SET
            C     EQUAL TO ZERO, AND KSW1 IS BLANK OR ZERO, THEN RDATNA WILL
            C     SET ANTFIL TO 5 AND LOOK FOR THE INPUT ANTENNA PATTERNS ON THE
            C     CARD INPUT FILE.   J. CLARK 11/76
            C
ISN 0049          CALL RDATNA
            C
            C
            C        SET MODE AND TIME TABLES TO ZERO
            C
ISN 0050       65 DO 70 I = 1, 30
ISN 0051          MODE(I) = 0
ISN 0052          TIME(I)=0.0
ISN 0053          FREQ(I)=0.0
ISN 0054       70 CONTINUE
            C
            C         INITIALIZE VARIABLES AND COUNTERS
            C
ISN 0055          DO 80 J=1,1000
ISN 0056       80 A(J) = 0.
ISN 0057          LIMIT = 0
ISN 0058          NTIME=0
ISN 0059          NFREQ = 0
ISN 0060          NCDS = 0
ISN 0061          OLDT=-1.0
ISN 0062          OLDFR=-1.0
ISN 0063          S1=0
ISN 0064          S2=0
ISN 0065          K=0
ISN 0066          N1=0
```

```
ISN 0067          READ (JF,905) HEADER                                          BRE10460
ISN 0068          PRINT 906, HEADER                                             BRE10470
ISN 0069          MX1 = 0                                                       BRE10480
ISN 0070          RETURN                                                        BRE10490
ISN 0071      900 FORMAT (3F10.0)                                               BRE10500
ISN 0072      903 FORMAT(16F5.0)                                                BRE10510
ISN 0073      904 FORMAT (1H ,I4,F12.1,14F6.1)                                  BRE10520
ISN 0074      905 FORMAT (7A8,I4,2F10.3)                                        BRE10530
ISN 0075      906 FORMAT (1H1, 10A8 //)                                         BRE10540
ISN 0076      910 FORMAT(2I5,2I10,I3,I4,I3,3F10.0,I10)                          BRE10550
ISN 0077      911 FORMAT(2X,15F5.0)                                             BRE10560
ISN 0078      912 FORMAT(' SW1=',I2,' SW2=',I2,' JCARD=',I2,' NOFREQ=',I2,' P=',    BRE10570
                 1 F10.3,' W/HZ,',2X,'BAUD=',E10.3,'SEC,  PLREJ=',E10.3,        BRE10580
                 2 'DB,  IBETA=',I2,/10X,' MAXANG= ',I3,'  ANTENNA FILE IS ',I5,    BRE10590
                 3 '  NEW ANT PAT = ',I3//)                                     BRE10600
ISN 0079      935 FORMAT(//5X,'*****     USE OLD ANTENNA PATTERNS REQUESTED',   BRE10610
                 1    'WHEN NO PREVIOUS PATTERNS AVAILABLE     .....',/20X,      BRE10620
                 2    'KSW1 SET SO THAT NO ANTENNA PATTERNS WILL BE USED     *****'/)BRE10630
ISN 0080          END                                                           BRE10640
```

```
LEVEL 2.1 ( JAN 75 )          INITLC          OS/360  FORTRAN H EXTENDED            DATE 77.271/15.33.00        PAGE   4

NUMBER    LEVEL                             FORTRAN H EXTENDED ERROR MESSAGES

IFE30/I    4(W)        NAME @@BLNK      THE DATA STATEMENT CONTAINS A VARIABLE THAT IS NOT REFERENCED.

*OPTIONS IN EFFECT*NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(0228K) AUTODBL(NONE)

*OPTIONS IN EFFECT*SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT GOSTMT NOXREF NOALC NOANSF TERMINAL FLAG(I)

*STATISTICS*      SOURCE STATEMENTS =       79, PROGRAM SIZE =      1932, SUBPROGRAM NAME =INITLC

*STATISTICS*     1 DIAGNOSTICS GENERATED, HIGHEST SEVERITY CODE IS  4

****** END OF COMPILATION ******                                          116K BYTES OF CORE NOT USED
```

```
REQUESTED OPTIONS: ID

OPTIONS IN EFFECT: NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(0228K) AUTODBL(NONE)
                   SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT GOSTMT NOXREF NOALC NOANSF TERMINAL FLAG(I)

  ISN 0002          SUBROUTINE ONE                                                  BRE10650
              C                                                                     BRE10660
              C        MAKES CALCULATIONS FOR A RAYPATH, COMBINES THESE CALCULATIONS  BRE10670
              C        FOR ALL RAYPATHS AT A GIVEN TIME AND FREQUENCY.              BRE10680
              C                                                                     BRE10690
              C         DECLARATION STATEMENTS                                      BRE10700
              C                                                                     BRE10710
              C         VARIABLES WHICH ARE READ IN FROM CARDS                      BRE10720
              C                                                                     BRE10730
  ISN 0003          COMMON T,M,FR,DT,DR,PL,N,PT1,TAU(60),GMT,BAUD,P                 BRE10740
              C                                                                     BRE10750
              C         VARIABLES WHICH ARE COMPUTED                                BRE10760
              C                                                                     BRE10770
  ISN 0004          COMMON LIMIT,NTIME,NFREQ,OLDT,OLDFR,OLDGMT,S1,S2,K,N1,NCDS      BRE10780
              C                                                                     BRE10790
              C         VARIABLE ARRAYS                                             BRE10800
              C                                                                     BRE10810
  ISN 0005          COMMON PT(1000,3),A(1000),PHASET(1000),TAUS(1000),              BRE10820
                   *       MODE(60),TIME(30),FREQ(30),                              BRE10830
                   *       SIGTAU(20,20),SIGNOI (20,20)                             BRE10840
  ISN 0006          COMMON /ANTDAT/ TABL1V(181,8),TABL1H(181,8),TABL2V(181,8),      BRE10850
                   *TABL2H(181,8),MXANGL(2),MNANGL(2),KRXN(2),NANGLS(2)             BRE10860
  ISN 0007          DIMENSION  PATHLS (60), SIGDB(60)                               BRE10870
  ISN 0008          INTEGER*4 OLDGMT,GMT                                            BRE10880
  ISN 0009          REAL N                                                          BRE10890
  ISN 0010          REAL MODE,M                                                     BRE10900
  ISN 0011          REAL MODEF                                                      BRE10910
  ISN 0012          COMMON/MIN/DBMIN,DTMIN,DRMIN                                    BRE10920
  ISN 0013          COMMON /CONTRO /  PLREJ                                         BRE10930
  ISN 0014          COMMON /SAVSIG/ HIRAYP, IFLAG                                   BRE10940
  ISN 0015          COMMON /DATA/ C2, FOURPI,  EFPL, TABLFR(15), IDUMM, MAX, IDEBUG BRE10950
              C                                                                     BRE10960
              C       ALOG10(C2/(FOURPI*1.E12))=3.8550326                           BRE10970
              C                                                                     BRE10980
              C                                                                     BRE10990
              C           ENTER HERE FOR EACH CARD                                  BRE11000
              C                                                                     BRE11010
  ISN 0016          TAU(N1) = TAU(N1)* 0.001                                        BRE11020
  ISN 0017          PT1 = PT1 * 1.0E-03                                             BRE11030
  ISN 0018          NOLD = N                                                        BRE11040
              C                                                                     BRE11050
              C        IF THE PATH LOSS IS GREATER THAN PLREJ DB OR IF THE TRANSMITTERBRE11060
              C        OR RECEIVER CANNOT BE CALIBRATED, IGNORE THIS CARD.          BRE11070
              C                                                                     BRE11080
  ISN 0019          IF(PL.LT.PLREJ) GO TO 5                                         BRE11090
  ISN 0021          PATHLS(N1) = PLREJ                                              BRE11100
  ISN 0022          GO TO 8                                                         BRE11110
  ISN 0023        5 CONTINUE                                                        BRE11120
  ISN 0024          GTV = F1(DT,TABL1V,1)                                           BRE11130
  ISN 0025          GTH=F1(DT,TABL1H,1)                                             BRE11140
  ISN 0026          GRV = F1(DR,TABL2V,2)                                           BRE11150
  ISN 0027          GRH=F1(DR,TABL2H,2)                                             BRE11160
  ISN 0028          SIGDB(N1) = 10.0*ALOG10(P*GTV*GRV/(FR*FR)) + 38.550326 - PL     BRE11170
```

```
ISN 0029          PATHLS(N1) = PL                                          BRE11180
              C                                                            BRE11190
              C   INITIALIZE VARIABLES FOR A GIVEN TIME AND/OR FREQUENCY   BRE11200
              C                                                            BRE11210
ISN 0030          IF(IFLAG.GT.0) GO TO 50                                  BRE11220
ISN 0032          IFLAG = 1                                                BRE11230
ISN 0033          HIRAYP = SIGDB(N1)                                       BRE11240
ISN 0034          SIGMAX = HIRAYP                                          BRE11250
ISN 0035          PATHMI = PL                                              BRE11260
ISN 0036          GO TO 8                                                  BRE11270
              C                                                            BRE11280
              C   UPDATE VALUES AS REQUIRED                                BRE11290
              C                                                            BRE11300
ISN 0037       50 CONTINUE                                                 BRE11310
ISN 0038          IF(PL.LT.PATHMI) PATHMI = PL                             BRE11320
ISN 0040          IF(SIGDB(N1).GT.SIGMAX) SIGMAX = SIGDB(N1)               BRE11330
ISN 0042          DIFF = SIGDB(N1) - HIRAYP                                BRE11340
ISN 0043          IF(DIFF.LT.-100.0) GO TO 8                               BRE11350
ISN 0045          IF(DIFF.LT.100.0) GO TO 60                               BRE11360
ISN 0047          HIRAYP = SIGDB(N1)                                       BRE11370
ISN 0048          GO TO 8                                                  BRE11380
ISN 0049       60 CONTINUE                                                 BRE11390
ISN 0050          PVAL = 1.00 + 10.0**(DIFF/10.0)                          BRE11400
ISN 0051          HIRAYP = HIRAYP + 10.0*ALOG10(PVAL)                      BRE11410
ISN 0052        8 K = K+1                                                  BRE11420
ISN 0053          TAUS(K) = TAU(N1)                                        BRE11430
ISN 0054          PT(K,1) = FR                                             BRE11440
ISN 0055          PT(K,3)=TIMEF(T)                                         BRE11450
ISN 0056          DO 821 I= 1,LIMIT                                        BRE11460
ISN 0057          IF (M.NE.MODE(I))  GO TO 821                             BRE11470
ISN 0059          GO TO 822                                                BRE11480
ISN 0060      821   CONTINUE                                               BRE11490
ISN 0061          PT(K,2)= 0.0                                             BRE11500
ISN 0062      822   PT(K,2)=I                                              BRE11510
              C   PT(K,2)=MODEF(M)                                         BRE11520
ISN 0063          PHASET(K) = PT1                                          BRE11530
ISN 0064          RETURN                                                   BRE11540
              C                                                            BRE11550
              C       ENTER HERE ON CHANGE OF FREQUENCY OR TIME            BRE11560
              C                                                            BRE11570
ISN 0065          ENTRY TWO                                                BRE11580
ISN 0066          S3 = 0.0                                                 BRE11590
ISN 0067          TWOSIG  = 0.                                             BRE11600
ISN 0068          N1 = N1 - 1                                              BRE11610
ISN 0069          PATHDI =0.                                               BRE11620
ISN 0070          GTV= F1(DTMIN,TABL1V,1)                                  BRE11630
ISN 0071          GTH=F1(DTMIN,TABL1H,1)                                   BRE11640
ISN 0072          GRV= F1(DRMIN,TABL2V,2)                                  BRE11650
ISN 0073          GTR=F1(DRMIN,TABL2H,2)                                   BRE11660
ISN 0074          SNMAX=10.*ALOG10(P*GTV*GRV /(FR*FR))+38.550326-DRMIN+NOLD BRE11670
ISN 0075       17 IF (OLDFR.EQ.-1.0) GO TO 12                              BRE11680
ISN 0077          GO TO 20                                                 BRE11690
ISN 0078       12 OLDGMT = GMT                                             BRE11700
ISN 0079          OLDFR=FR                                                 BRE11710
ISN 0080          OLDT=T                                                   BRE11720
ISN 0081       20 CONTINUE                                                 BRE11730
ISN 0082          IF(IFLAG.EQ.0) GO TO 215                                 BRE11740
ISN 0084          MIN = MAX + 1                                            BRE11750
```

```
ISN 0085            MX=MAX + N1                                                    BRE11760
               C                                                                    BRE11770
               C       J RELATES TO K-LOOP BETWEEN ASTERISKS, I TO N1-LOOP BETWEEN  BRE11780
               C           TIMES AND FREQ                                           BRE11790
               C                                                                    BRE11800
ISN 0086            DO 210 J=MIN,MX                                                BRE11810
ISN 0087            I=J-MAX                                                        BRE11820
ISN 0088            IF(PATHLS (I).EQ.PLREJ) GO TO 210                              BRE11830
ISN 0090        201 IF(PATHLS (I).GT.(PATHMI +30.)) GO TO 202                      BRE11840
ISN 0092        200 PATHDI = 10.**((PATHMI -PATHLS (I))/10.) + PATHDI              BRE11850
ISN 0093        202 IF(SIGDB(I).LT.(SIGMAX-30.)) GO TO 210                         BRE11860
               C                                                                    BRE11870
               C       REDUCED AMPLITUTE A() CAN BE USED IN MEAN AND SIGMA CALC     BRE11880
               C                                                                    BRE11890
ISN 0095        205 A(J)=10.**((SIGDB(I)-SIGMAX)/10.)                              BRE11900
ISN 0096            S1 = S1 + A(J)                                                 BRE11910
ISN 0097            S2 = S2 + A(J)*TAU(I)                                          BRE11920
ISN 0098        210 CONTINUE                                                       BRE11930
               C                                                                    BRE11940
ISN 0099            IF(S1.GT.0.0) GO TO 82                                         BRE11950
ISN 0101        215 CONTINUE                                                       BRE11960
ISN 0102            S = -1.0E75                                                    BRE11970
ISN 0103            TAUBAR=0.0                                                     BRE11980
ISN 0104            TWOSIG=0.0                                                     BRE11990
               C    SN = -1.E100                                                   BRE12000
ISN 0105            SN = -1.E70                                                    BRE12010
ISN 0106            GO TO 25                                                       BRE12020
ISN 0107         82 TAUBAR = S2/S1                                                 BRE12030
ISN 0108            IF (N1 .EQ. 1) GO TO 21                                        BRE12040
ISN 0110          9 DO 10 J = MIN, MX                                              BRE12050
ISN 0111            S3 = S3 + A(J) * (TAUS(J) - TAUBAR)**2                         BRE12060
ISN 0112         10 CONTINUE                                                       BRE12070
ISN 0113            TWOSIG =2.0*SQRT(S3/S1)                                        BRE12080
ISN 0114         21 S = SIGMAX + 10.*ALOG10(S1)                                    BRE12090
ISN 0115            SN = S + NOLD                                                  BRE12100
ISN 0116         25 TAUBAR = TAUBAR * 1000.0                                       BRE12110
ISN 0117            S = -S                                                         BRE12120
ISN 0118            IF (N1 .EQ. 1) GO TO 29                                        BRE12130
ISN 0120         28 TWOSIG  = TWOSIG  * 1000.                                      BRE12140
ISN 0121         29 IF(PATHDI .EQ.0.) GO TO 27                                     BRE12150
ISN 0123         26 EFPL= PATHMI  - 10.*ALOG10(PATHDI )                            BRE12160
ISN 0124         27 IF(S1.EQ. 0.)  GO TO 265                                       BRE12170
ISN 0126            GO TO 275                                                      BRE12180
ISN 0127        265 PRINT 903, OLDGMT,OLDT,OLDFR,N1                                BRE12190
ISN 0128            GO TO 30                                                       BRE12200
ISN 0129        275 PRINT 900, OLDGMT,OLDT,OLDFR,N1,TAUBAR,TWOSIG ,S,SN,EFPL,SNMAX BRE12210
ISN 0130         30 I = FREQF(OLDFR)                                               BRE12220
ISN 0131            J = TIMEF(OLDT)                                                BRE12230
ISN 0132            SIGNOI (I,J) = SN                                              BRE12240
ISN 0133            SIGTAU(I,J) = TWOSIG  * .001                                   BRE12250
ISN 0134            EFPL = 0.0                                                     BRE12260
ISN 0135            DO 31 I=1,60                                                   BRE12270
ISN 0136            SIGDB(I)=0.0                                                   BRE12280
ISN 0137         31 PATHLS (I)= 0.0                                                BRE12290
ISN 0138            MAX=MX                                                         BRE12300
ISN 0139            TAU(1) = TAU(N1+1)                                             BRE12310
ISN 0140            OLDGMT = GMT                                                   BRE12320
ISN 0141            OLDFR=FR                                                       BRE12330
```

```
  ISN 0142           OLDT=T                                                           BRE12340
  ISN 0143           N1=1                                                             BRE12350
  ISN 0144           S1=0.0                                                           BRE12360
  ISN 0145           S2=0.0                                                           BRE12370
  ISN 0146           HIRAYP = -1.0E75                                                 BRE12380
  ISN 0147           IFLAG = 0                                                        BRE12390
  ISN 0148           RETURN                                                           BRE12400
  ISN 0149       900 FORMAT (1H ,I10,F7.0,F7.1,I6,2F12.4,4E15.3)                      BRE12410
  ISN 0150       903 FORMAT (1H ,I10,F7.0,F7.1,I6,                                    BRE12420
                    1   36H          NO IONOSPHERIC PROPOGATION)                      BRE12430
  ISN 0151           END                                                              BRE12440

*OPTIONS IN EFFECT*NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(0228K) AUTODBL(NONE)

*OPTIONS IN EFFECT*SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT GOSTMT NOXREF NOALC NOANSF TERMINAL FLAG(I)

*STATISTICS*     SOURCE STATEMENTS =     150, PROGRAM SIZE =     4012, SUBPROGRAM NAME =@@@ONE

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                                    104K BYTES OF CORE NOT USED
```

```
LEVEL 2.1  ( JAN 75 )                    OS/360  FORTRAN H EXTENDED              DATE 77.271/15.34.06        PAGE   1

REQUESTED OPTIONS: ID

OPTIONS IN EFFECT: NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(0228K) AUTODBL(NONE)
                   SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT GOSTMT NOXREF NOALC NOANSF TERMINAL FLAG(I)

   ISN 0002               SUBROUTINE RDATNA                                                  BRE12450
                    C                                                                        BRE12460
                    C   THIS SUBROUTINE READS ANTENNA PATTERNS WHEN THEY ARE SUUPLIED        BRE12470
                    C                                                                        BRE12480
   ISN 0003               COMMON /ANTDAT/ TABL1V(181,8),TABL1H(181,8),TABL2V(181,8),         BRE12490
                         *TABL2H(181,8),MXANGL(2),MNANGL(2),KRXN(2),NANGLS(2)               BRE12500
   ISN 0004               COMMON /DATA/ C2, FOURPI,  EFPL, TABLFR(15), ISW, MX1, IDEBUG      BRE12510
   ISN 0005               COMMON /SPPASS/ IANT,ANTFIL,VGTOT,RGTOT,HGTOT                      BRE12520
   ISN 0006               DIMENSION  ANGLGV(8), ANGLGH(8), LINVAL(4), NUMVAL(10)             BRE12530
   ISN 0007               INTEGER ANTFIL, OFFSET, PRINT                                      BRE12540
   ISN 0008               DATA PRINT/4HPRNT/                                                 BRE12550
   ISN 0009               NAMELIST /TRDATA/TABL1V,TABL1H,MAXANG,MINANG,OFFSET,NUMANG         BRE12560
   ISN 0010               NAMELIST /RCDATA/TABL2V,TABL2H,MAXANG,MINANG,OFFSET,NUMANG         BRE12570
   ISN 0011               VGTOT = 0.000                                                      BRE12580
   ISN 0012               HGTOT = 0.000                                                      BRE12590
   ISN 0013               K = 0                                                              PRE12600
   ISN 0014               LINES = 0                                                          BRE12610
   ISN 0015               LINCNT = -99999                                                    BRE12620
                    C                                                                        BRE12630
                    C   DEFAULT ANTFIL TO 5 TO READ PATTERNS FROM CARDS SO THAT              BRE12640
                    C     THIS CHANGE WILL BE INVISIBLE TO THE USER                          BRE12650
                    C                                                                        BRE12660
                    C                                                                        BRE12670
                    C   USE NUMANG = MAXANG + OFFSET AS END OF DATA MARKER                   BRE12680
                    C     TO ALLOW FOR ZERO OR NEGATIVE ANGLES E.G. -PI/2                    BRE12690
                    C                                                                        BRE12700
                    C                                                                        BRE12710
                    C     INITIALIZE FREQUENCY VECTOR AND GAIN TABLES                        BRE12720
                    C                                                                        BRE12730
   ISN 0016               DO 25 I = 1, IANT                                                  BRE12740
   ISN 0017               TABLFR(I) = 1.00                                                   BRE12750
   ISN 0018            25 CONTINUE                                                           BRE12760
   ISN 0019               DO 50 I = 1, 181                                                   BRE12770
   ISN 0020                 DO 50 J = 1, IANT                                                BRE12780
   ISN 0021                   TABL1V(I,J) = 1.00                                             BRE12790
   ISN 0022                   TABL1H(I,J) = 1.00                                             BRE12800
   ISN 0023                   TABL2V(I,J) = 1.00                                             BRE12810
   ISN 0024                   TABL2H(I,J) = 1.00                                             BRE12820
   ISN 0025            50 CONTINUE                                                           BRE12830
                    C                                                                        BRE12840
                    C     DETERMINE FEEDBACK REQUIREMENTS FOR ANTENNA PATTERNS               BRE12850
                    C                                                                        BRE12860
   ISN 0026               READ(5,902) NPRNT, LINES                                           BRE12870
   ISN 0027               IF(NPRNT.NE.PRINT) GO TO 80                                        BRE12880
   ISN 0029               IF(LINES.GT.NUMANG) LINES = NUMANG                                 BRE12890
   ISN 0031               LINCNT = LINES                                                     BRE12900
   ISN 0032               PRINT 905                                                          BRE12910
   ISN 0033            80 CONTINUE                                                           BRE12920
                    C                                                                        BRE12930
                    C READ FREQUENCY LIST                                                    BRE12940
                    C                                                                        BRE12950
   ISN 0034               READ(5,910) (TABLFR(I), I = 1,IANT)                                BRE12960
   ISN 0035               IF(NPRNT.NE.PRINT) GO TO 90                                        BRE12970
```

```
ISN 0037          PRINT 915, (TABLFR(I),I = 1,IANT)                          BRE12980
ISN 0038       90 CONTINUE                                                    BRE12990
           C                                                                  BRE13000
           C      READ GAIN DATA PRINT IF REQUIRED AND CONVERT TO RELATIVE POWER    BRE13010
           C                                                                  BRE13020
ISN 0039          DO 95 ICT = 1,2                                             BRE13030
ISN 0040            KRXN(ICT) = 1 - MNANGL(ICT)                               BRE13040
ISN 0041            NANGLS(ICT) = MXANGL(ICT) + KRXN(ICT)                     BRE13050
ISN 0042       95 CONTINUE                                                    BRE13060
ISN 0043          NUMANG = NANGLS(1)                                          BRE13070
ISN 0044          OFFSET = KRXN(1)                                            BRE13080
ISN 0045          MAXANG = MXANGL(1)                                          BRE13090
ISN 0046          MINANG = MNANGL(1)                                          BRE13100
ISN 0047          DO 150 I = 1, NUMANG                                        BRE13110
ISN 0048          READ(ANTFIL,901,END=500) IANG, (ANGLGV(IFREQ), IFREQ = 1,IANT)    BRE13120
ISN 0049            IF(IANG.LE.MAXANG.AND.IANG.GE.MINANG) GO TO 105           BRE13130
ISN 0051              PRINT 950                                               BRE13140
ISN 0052              PRINT 951, IANG, (ANGLGV(IFREQ),IFREQ = 1,IANT)         BRE13150
ISN 0053              READ(ANTFIL,901,END=500) IANG, (ANGLGH(IFREQ), IFREQ = 1,IANT)BRE13160
ISN 0054              PRINT 951, IANG, (ANGLGH(IFREQ),IFREQ = 1,IANT)         BRE13170
ISN 0055              GO TO 150                                               BRE13180
ISN 0056      105 CONTINUE                                                    BRE13190
ISN 0057          JANG = IANG                                                 BRE13200
ISN 0058          K = IANG + OFFSET                                           BRE13210
ISN 0059          DO 115 J = 1,IANT                                           BRE13220
ISN 0060            TABL1V(K,J) = 10.0**(ANGLGV(J)/10.0)                      BRE13230
ISN 0061      115 CONTINUE                                                    BRE13240
ISN 0062          READ(ANTFIL,901,END=500) IANG, (ANGLGH(IFREQ), IFREQ = 1,IANT)    BRE13250
ISN 0063            IF(IANG.EQ.JANG) GO TO 125                                BRE13260
ISN 0065            IF(IANG.LE.MAXANG.AND.IANG.GE.MINANG) GO TO 120           BRE13270
ISN 0067              PRINT 961, IANG, (ANGLGH(IFREQ), IFREQ = 1,IANT)        BRE13280
           C                                                                  BRE13290
           C    STOP PROCESSING BECAUSE HORIZONTAL IS OUT OF RANGE AND        BRE13300
           C      OUT OF SYNC                                                 BRE13310
           C                                                                  BRE13320
ISN 0068              STOP 00001                                              BRE13330
ISN 0069      120 CONTINUE                                                    BRE13340
ISN 0070            PRINT 955, IANG, (ANGLGH(IFREQ), IFREQ = 1,IANT)          BRE13350
ISN 0071      125 CONTINUE                                                    BRE13360
ISN 0072          K = IANG + OFFSET                                           BRE13370
ISN 0073          DO 135 J = 1,IANT                                           BRE13380
ISN 0074            TABL1H(K,J) = 10.0**(ANGLGH(J)/10.0)                      BRE13390
ISN 0075      135 CONTINUE                                                    BRE13400
ISN 0076          LINCNT = LINCNT + 1                                         BRE13410
ISN 0077          IF(LINCNT.LT.LINES) GO TO 150                               BRE13420
ISN 0079          LINCNT = 0                                                  BRE13430
ISN 0080          PRINT 920, IANG, (ANGLGV(J), ANGLGH(J), J=1,IANT)           BRE13440
ISN 0081      150 CONTINUE                                                    BRE13450
ISN 0082          IF(IDEBUG.GT.10) WRITE(6,TRDATA)                            BRE13460
           C                                                                  BRE13470
           C    READ AND PROCESS RECEIVER PATTERNS                            BRE13480
           C                                                                  BRE13490
ISN 0084          IF(NPRNT.NE.PRINT) GO TO 190                                BRE13500
ISN 0086          PRINT 925                                                   BRE13510
ISN 0087          LINCNT = LINES                                              BRE13520
ISN 0088          PRINT 915, (TABLFR(I),I = 1,IANT)                           BRE13530
ISN 0089      190 CONTINUE                                                    BRE13540
ISN 0090          NUMANG = NANGLS(2)                                          BRE13550
```

```
ISN 0091          OFFSET = KRXN(2)                                                  BRE13560
ISN 0092          MAXANG = MXANGL(2)                                                BRE13570
ISN 0093          MINANG = MNANGL(2)                                                BRE13580
ISN 0094          DO 250 I = 1, NUMANG                                              BRE13590
ISN 0095          READ(ANTFIL,901,END=500) IANG, (ANGLGV(IFREQ), IFREQ = 1,IANT)    BRE13600
ISN 0096            IF(IANG.LE.MAXANG.AND.IANG.GE.MINANG) GO TO 205                 BRE13610
ISN 0098              PRINT 950                                                     BRE13620
ISN 0099              PRINT 951, IANG, (ANGLGV(IFREQ),IFREQ = 1,IANT)               BRE13630
ISN 0100              READ(ANTFIL,901,END=500) IANG, (ANGLGH(IFREQ), IFREQ = 1,IANT)BRE13640
ISN 0101              PRINT 951, IANG, (ANGLGH(IFREQ),IFREQ = 1,IANT)               BRE13650
ISN 0102              GO TO 250                                                     BRE13660
ISN 0103      205 CONTINUE                                                          BRE13670
ISN 0104          JANG = IANG                                                       BRE13680
ISN 0105          K = IANG + OFFSET                                                 BRE13690
ISN 0106          DO 215 J = 1,IANT                                                 BRE13700
ISN 0107            PATVAL = 10.0**(ANGLGV(J)/10.0)                                 BRE13710
ISN 0108            TABL2V(K,J) = PATVAL                                            BRE13720
ISN 0109            VGTOT = VGTOT + PATVAL                                          BRE13730
ISN 0110      215 CONTINUE                                                          BRE13740
ISN 0111          READ(ANTFIL,901,END=500) IANG, (ANGLGH(IFREQ), IFREQ = 1,IANT)    BRE13750
ISN 0112            IF(IANG.EQ.JANG) GO TO 225                                      BRE13760
ISN 0114            IF(IANG.LE.MAXANG.AND.IANG.GE.MINANG) GO TO 220                 BRE13770
ISN 0116              PRINT 961, IANG, (ANGLGH(IFREQ), IFREQ = 1,IANT)              BRE13780
            C                                                                       BRE13790
            C   STOP PROCESSING BECAUSE HORIZONTAL IS OUT OF RANGE AND              BRE13800
            C     OUT OF SYNC                                                       BRE13810
            C                                                                       BRE13820
ISN 0117              STOP 00002                                                    BRE13830
ISN 0118      220 CONTINUE                                                          BRE13840
ISN 0119            PRINT 955, IANG, (ANGLGH(IFREQ), IFREQ = 1,IANT)                BRE13850
ISN 0120      225 CONTINUE                                                          BRE13860
ISN 0121          K = IANG + OFFSET                                                 BRE13870
ISN 0122          DO 235 J = 1,IANT                                                 BRE13880
ISN 0123            PATVAL = 10.0**(ANGLGH(J)/10.0)                                 BRE13890
ISN 0124            TABL2H(K,J) = PATVAL                                            BRE13900
ISN 0125            HGTOT = HGTOT + PATVAL                                          BRE13910
ISN 0126      235 CONTINUE                                                          BRE13920
ISN 0127          LINCNT = LINCNT +1                                                BRE13930
ISN 0128          IF(LINCNT.LT.LINES) GO TO 250                                     BRE13940
ISN 0130          PRINT 920, IANG,(ANGLGV(J), ANGLGH(J), J = 1,IANT)                BRE13950
ISN 0131          LINCNT = 0                                                        BRE13960
ISN 0132      250 CONTINUE                                                          BRE13970
ISN 0133          IF(IDEBUG.GT.10) WRITE(6,RCDATA)                                  BRE13980
ISN 0135          RGTOT = VGTOT + HGTOT                                             BRE13990
ISN 0136          RETURN                                                            BRE14000
ISN 0137      500 CONTINUE                                                          BRE14010
ISN 0138          RGTOT = HGTOT + VGTOT                                             BRE14020
ISN 0139          IANG = K - OFFSET                                                 BRE14030
ISN 0140          PRINT 522, IANG                                                   BRE14040
ISN 0141      522 FORMAT(//10X,50(1H*),//13X,                                       BRE14050
             1    'DATA ENDS UNEXPECTEDLY WITH ANGLE =',I5,                         BRE14060
             2    /15X,'DESIRED DATA MAY BE REPLACED BY ONES',                      BRE14070
             3   //10X,50(1H*)//)                                                   BRE14080
ISN 0142          RETURN                                                            BRE14090
ISN 0143      901 FORMAT(I5,8F5.0)                                                  BRE14100
ISN 0144      902 FORMAT(A4,I6)                                                     BRE14110
ISN 0145      905 FORMAT(/,5X,'TRANSMITTER GAIN(DB)   ANGLE(DEG) BY FREQUENCY(MHZ)',BRE14120
             1    /25X,'FREQUENCY'/)                                                BRE14130
```

```
  ISN 0146        910 FORMAT(8F5.0)                                                   BRE14140
  ISN 0147        915 FORMAT(/10X,8(2X,F10.4,2X))                                     BRE14150
  ISN 0148        920 FORMAT(3X,I4,3X,16(F6.2,1X))                                    BRE14160
  ISN 0149        925 FORMAT(/,5X'RECEIVER GAIN(DB)  ANGLE(DEG) BY FREQUENCY(MHZ)',   BRE14170
                     1   /25X,'FREQUENCY'/)                                           BRE14180
  ISN 0150        950 FORMAT(// 5X,'*****     ANGLE READ OUTSIDE OF SPECIFIED RANGE ',BRE14190
                     1 ' ..... VERTICAL AND HORIZONTAL DATA LOST AS FOLLOWS -')       BRE14200
  ISN 0151        951 FORMAT( 20X,I5,3X,8(G5.0,3X))                                   BRE14210
  ISN 0152        955 FORMAT(//5X,'*****      HORIZONTAL DATA OUT OF SYNC',           BRE14220
                     1  ' DATA SAVED AS FOLLOWS -',/20X,I5,3X,8(G5.0,3X))             BRE14230
  ISN 0153        961 FORMAT(//10X,'.....  STOP PROCESSING',                          BRE14240
                     1  ' HORIZONTAL ANGLE OUT OF SYNC AND OUT OF RANGE, SIC -',      BRE14250
                     2  /20X,I5,3X,8(G5.0,3X))                                        BRE14260
  ISN 0154            END                                                             BRE14270

*OPTIONS IN EFFECT*NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(0228K) AUTODBL(NONE)

*OPTIONS IN EFFECT*SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT GOSTMT NOXREF NOALC NOANSF TERMINAL FLAG(I)

*STATISTICS*     SOURCE STATEMENTS =     153, PROGRAM SIZE =     4432, SUBPROGRAM NAME =RDATNA

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                                    96K BYTES OF CORE NOT USED
```

```
LEVEL 2.1  ( JAN 75 )                    OS/360  FORTRAN H EXTENDED            DATE 77.271/15.34.33        PAGE    1

REQUESTED OPTIONS: ID

OPTIONS IN EFFECT: NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(0228K) AUTODBL(NONE)
                   SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT GOSTMT NOXREF NOALC NOANSF TERMINAL FLAG(I)

   ISN 0002            SUBROUTINE READ                                                  BRE14280
              C                                                                         BRE14290
              C           READS THE DATA CARD AND BUILDS TABLES FOR MODES, TIMES, AND   BRE14300
              C           FREQUENCIES.                                                  BRE14310
              C                                                                         BRE14320
              C                                                                         BRE14330
              C            DECLARATION STATEMENTS                                       BRE14340
              C                                                                         BRE14350
              C            VARIABLES WHICH ARE READ IN FROM CARDS                       BRE14360
              C                                                                         BRE14370
   ISN 0003            COMMON T,M,FR,DT,DR,PL,N,PT1,TAU(60),GMT,BAUD,P                  BRE14380
              C                                                                         BRE14390
              C            VARIABLES WHICH ARE COMPUTED                                 BRE14400
              C                                                                         BRE14410
   ISN 0004            COMMON LIMIT,NTIME,NFREQ,OLDT,OLDFR,OLDGMT,S1,S2,K,N1,NCDS       BRE14420
              C                                                                         BRE14430
              C            VARIABLE ARRAYS                                              BRE14440
              C                                                                         BRE14450
   ISN 0005            COMMON PT(1000,3),A(1000),PHASET(1000),TAUS(1000),               BRE14460
                      *       MODE(60),TIME(30),FREQ(30),                               BRE14470
                      *       SIGTAU(20,20),SIGNOI (20,20)                              BRE14480
   ISN 0006            COMMON /ANTDAT/ TABL1V(181,8),T BL1H(181,8),TABL2V(181,8),       BRE14490
                      *TABL2H(181,8),MXANGL(2),MNANGL(2),KRXN(2),NANGLS(2)              BRE14500
   ISN 0007            COMMON /DATA/ C2, FOURPI,  EFPL, TABLFR(15), IDUMM, MAX, IDEBUG  BRE14510
   ISN 0008            COMMON/XLIT/AST,LIN,BLANK,STAR                                   BRE14520
   ISN 0009            DIMENSION LIN(20)                                                BRE14530
   ISN 0010            INTEGER*4 AST,LIN,BLANK,STAR                                     BRE14540
   ISN 0011            INTEGER*4 OLDGMT,GMT,GGG                                         BRE14550
   ISN 0012            DATA GGG/1HG/                                                    BRE14560
   ISN 0013            REAL N                                                           BRE14570
   ISN 0014            REAL MODE, M                                                     BRE14580
   ISN 0015            COMMON/MIN/DBMIN,DTMIN,DRMIN                                     BRE14590
   ISN 0016            COMMON/SWITCH/KSW1,KSW2,JF,IBETA                                 BRE14600
              C                                                                         BRE14610
              C   GIVE INPUT VARIABLES ALIASES FOR USE IN BREM CALCULATIONS             BRE14620
              C                                                                         BRE14630
   ISN 0017            EQUIVALENCE (M,FACHNZ), (PT1,THT), (PL,RHT)                      BRE14640
   ISN 0018          4 N1 = N1+1                                                        BRE14650
   ISN 0019          5 READ(JF,900,END=50)ISW,T,M,FX,DT,DR,TAU(N1),PT1,PL,N,GMT,PLBETA  BRE14660
   ISN 0020            IF(ISW.EQ.GGG)GO TO 200                                          BRE14670
   ISN 0022          6 IF (ISW .EQ. STAR) GO TO 30                                      BRE14680
   ISN 0024            WRITE(6,906)ISW,T,M,FX,DT,DR,TAU(N1),PT1,PL,N,GMT,PLBETA         BRE14690
   ISN 0025          7 NCDS = NCDS + 1                                                  BRE14700
   ISN 0026            FR=FX                                                            BRE14710
   ISN 0027            IF(IBETA.EQ.1) PL=PLBETA                                         BRE14720
   ISN 0029            IF(M) 62,62,8                                                    BRE14730
   ISN 0030         62 DBMIN=PL                                                         BRE14740
   ISN 0031            DTMIN=DT                                                         BRE14750
   ISN 0032            DRMIN=DR                                                         BRE14760
   ISN 0033            GO TO 5                                                          BRE14770
   ISN 0034          8 CONTINUE                                                         BRE14780
   ISN 0035            IF (NCDS .LE. 1000)  GO TO 20                                    BRE14790
   ISN 0037            GO TO 100                                                        BRE14800
```

```
                C                                                                BRE14810
                C         BUILD TABLE OF MODES                                   BRE14820
                C                                                                BRE14830
  ISN 0038         20 IF (LIMIT .GT. 0) GO TO 21                                 BRE14840
  ISN 0040            GO TO 23                                                   BRE14850
  ISN 0041         21 DO 22 I = 1,LIMIT                                          BRE14860
  ISN 0042            IF (M .NE. MODE(I)) GO TO 22                               BRE14870
  ISN 0044            GO TO 24                                                   BRE14880
  ISN 0045         22 CONTINUE                                                   BRE14890
  ISN 0046         23 LIMIT = LIMIT + 1                                          BRE14900
  ISN 0047            IF (LIMIT .GT. 60) GO TO 110                               BRE14910
  ISN 0049         43 MODE(LIMIT) = M                                            BRE14920
                C                                                                BRE14930
                C         BUILD TABLE OF TIMES                                   BRE14940
                C                                                                BRE14950
                C                                                                BRE14960
                C         IF TIME = -1, USE GMT INSTEAD                          BRE14970
                C                                                                BRE14980
  ISN 0050         24 IF (T .EQ. -1.0) GO TO 40                                  BRE14990
  ISN 0052            GO TO 41                                                   BRE15000
  ISN 0053         40 IGMT1 = GMT / 100                                          BRE15010
  ISN 0054            IGMT2 = GMT - IGMT1 * 100                                  BRE15020
  ISN 0055            T = IGMT1 * 3600 + IGMT2 * 60                              BRE15030
  ISN 0056         41 IF (NTIME .GT. 0) GO TO 25                                 BRE15040
  ISN 0058            GO TO 27                                                   BRE15050
  ISN 0059         25 DO 26 I = 1, NTIME                                         BRE15060
  ISN 0060            IF (T .NE. TIME(I)) GO TO 26                               BRE15070
  ISN 0062            GO TO 28                                                   BRE15080
  ISN 0063         26 CONTINUE                                                   BRE15090
  ISN 0064         27 NTIME = NTIME + 1                                          BRE15100
  ISN 0065            IF (NTIME .GT. 20) GO TO 120                               BRE15110
  ISN 0067         44 TIME(NTIME) = T                                            BRE15120
                C                                                                BRE15130
                C          BUILD TABLE OF FREQUENCIES                            BRE15140
                C                                                                BRE15150
  ISN 0068         28 IF (NFREQ.GT. 0)  GO TO 35                                 BRE15160
  ISN 0070            GO TO 37                                                   BRE15170
  ISN 0071         35 DO 36 I = 1, NFREQ                                         BRE15180
  ISN 0072            IF (FR .NE. FREQ(I)) GO TO 36                              BRE15190
  ISN 0074            GO TO 38                                                   BRE15200
  ISN 0075         36 CONTINUE                                                   BRE15210
  ISN 0076         37 NFREQ = NFREQ + 1                                          BRE15220
  ISN 0077            IF (NFREQ .GT. 20) GO TO 130                               BRE15230
  ISN 0079         45 FREQ(NFREQ) = FR                                           BRE15240
  ISN 0080         38 RETURN                                                     BRE15250
                C                                                                BRE15260
                C         END OF FILE PROCESSING                                 BRE15270
                C                                                                BRE15280
  ISN 0081        200 CONTINUE                                                   BRE15290
  ISN 0082            APOW=10.0*ALOG10(P)                                        BRE15300
  ISN 0083            THT = 0.001*THT                                            BRE15310
  ISN 0084            RHT = 0.001*RHT                                            BRE15320
  ISN 0085            IF(FACHNZ.LE.0.00) FACHNZ = 0.02                           BRE15330
  ISN 0087            CALL CPOWER(APOW,TP,ALPSUM)                                BRE15340
                C                                                                BRE15350
                C   RETURN TO READ NEXT INPUT WITHOUT INCREMENTING N1            BRE15360
                C                                                                BRE15370
  ISN 0088            GO TO 5                                                    BRE15380
```

```
ISN 0089        30 CALL TWO                                                    BRE15390
ISN 0090           CALL PRINTP                                                 BRE15400
ISN 0091           CALL INITIA                                                 BRE15410
ISN 0092           GO TO 4                                                     BRE15420
ISN 0093        50 CALL TWO                                                    BRE15430
ISN 0094           CALL PRINTP                                                 BRE15440
ISN 0095           STOP                                                        BRE15450
ISN 0096       100 PRINT 902                                                   BRE15460
ISN 0097           STOP 2                                                      BRE15470
ISN 0098       110 PRINT 903                                                   BRE15480
ISN 0099           STOP 3                                                      BRE15490
ISN 0100       120 PRINT 904                                                   BRE15500
ISN 0101           STOP 4                                                      BRE15510
ISN 0102       130 PRINT 905                                                   BRE15520
ISN 0103           STOP 5                                                      BRE15530
ISN 0104       900 FORMAT (A1,F6.0,F10.0,3F6.2,2F7.3,F9.1,F7.1,I5,F10.1)       BRE15540
ISN 0105       906 FORMAT (/2X,A1,F6.0,F10.0,3F6.2,2F7.3,F9.1,F7.1,I5,F10.1)   BRE15550
ISN 0106       901 FORMAT(F10.3)                                               BRE15560
ISN 0107       902 FORMAT (40H TOO MANY INPUT CARDS -- MAXIMUM = 1000  )       BRE15570
ISN 0108       903 FORMAT (21H1TOO MANY MODES       )                          BRE15580
ISN 0109       904 FORMAT (21H1TOO MANY TIMES       )                          BRE15590
ISN 0110       905 FORMAT (21H1TOO MANY FREQUENCIES)                           BRE15600
ISN 0111           END                                                         BRE15610

*OPTIONS IN EFFECT*NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(0228K) AUTODBL(NONE)

*OPTIONS IN EFFECT*SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT GOSTMT NOXREF NOALC NOANSF TERMINAL FLAG(I)

*STATISTICS*     SOURCE STATEMENTS =     110, PROGRAM SIZE =     2070, SUBPROGRAM NAME =@@READ

*STATISTICS*  NO  DIAGNOSTICS GENERATED

****** END OF COMPILATION ******                          108K BYTES OF CORE NOT USED
```

```
REQUESTED OPTIONS: ID

OPTIONS IN EFFECT: NAME(MAIN) NOOPTIMIZE LINECOUNT(60) SIZE(0228K) AUTODBL(NONE)
                   SOURCE EBCDIC NOLIST NODECK OBJECT NOMAP NOFORMAT GOSTMT NOXREF NOALC NOANSF TERMINAL FLAG(I)

   ISN 0002        BLOCK DATA                                                             BRE15620
   ISN 0003        COMMON /ANTDAT/ TABL1V(181,8),TABL1H(181,8),TABL2V(181,8),             BRE15630
                  *TABL2H(181,8),MXANGL(2),MNANGL(2),KRXN(2),NANGLS(2)                    BRE15640
   ISN 0004        COMMON /DATA/ C2, FOURPI,  EFPL, TABLER(15), IDUMM, MAX, IDEBUG        BRE15650
   ISN 0005        COMMON /SPPASS/ NOFREQ,INPFIL,VGTOT,RGTOT,HGTOT                        BRE15660
   ISN 0006        COMMON /SAVSIG/ HIRAYP, IFLAG                                          BRE15670
   ISN 0007        COMMON/SWITCH/KSW1,KSW2,JF,IBETA,JCARD,NEWANT                          BRE15680
   ISN 0008        COMMON/XLIT/AST,LIN,BLANK,STAR                                         BRE15690
   ISN 0009        DIMENSION LIN(20)                                                      BRE15700
   ISN 0010        INTEGER*4 AST,LIN,BLANK,STAR                                           BRE15710
   ISN 0011        DATA AST/'****'/                                                       BRE15720
   ISN 0012        DATA LIN/'PHAS','E  *','DOPP','LER*','SIGL','AM *','SIGT','AU *',      BRE15730
                  1'SDBE','    *','DDBE','    *','SDBE','-DS*','DDBE','-DS*',4*'    '/    BRE15740
   ISN 0013        DATA BLANK/'    '/                                                     BRE15750
   ISN 0014        DATA STAR /1H*/                                                        BRE15760
   ISN 0015        DATA HIRAYP/-1.0E75/, IFLAG/-1/, NEWANT,KSW1/2*1/,JF/7/                BRE15770
   ISN 0016        DATA KSW2, JCARD, IBETA/3*0/, INPFIL/5/, NOFREQ /1/                    BRE15780
   ISN 0017        DATA MXANGL, MNANGL, NANGLS /90, 90, -90, -90, 181, 181/               BRE15790
   ISN 0018        DATA  C2, FOURPI, EFPL, MAX /9.0E16, 12.5663706, 0.0, 0/               BRE15800
   ISN 0019        DATA VGTOT, RGTOT, HGTOT /3*1.0/, IDEBUG /0/                           BRE15810
   ISN 0020        END                                                                    BRE15820
```

APPENDIX D

Supplement to NUCOM II Users Guide

The modifications to NUCOM II to produce the NUCOM/BREM version were designed to minimize the changes to existing NUCOM II deck setup and case stacking logic. In RAYTRACE one new control card has been added to input the problem description for the nonionospheric modes.

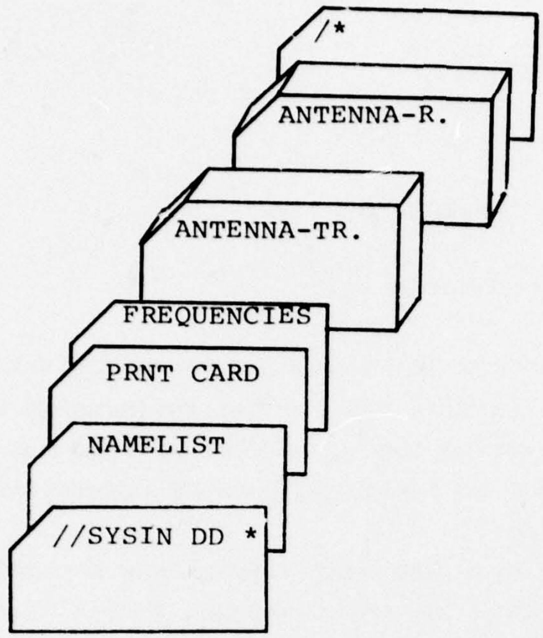
In COMEFF the CARD 1 input has been altered and a namelist input feature has been added. The input antenna format has been altered slightly to permit inclusion of horizontal as well as vertical polarization parameters.

These new input cards are described as follows:

BREM INPUT CARD - RAYTRACE

BREM DESCRIPTION

NAME	FORMAT	COLUMNS	DESCRIPTION	UNITS	COMMENTS
HTR	F10.3	1-10	TRANSMITTER HEIGHT	METERS	
HTT	F10.3	11-20	RECEIVER HEIGHT	METERS	
SIGMA	F10.5	21-30	USER SIGMA	Mho/m	TO OVERRIDE NWOMAP
EPSILON	F10.5	31-40	USER EPSILON		
WNDVEL	F10.5	41-50	WIND VELOCITY	m/sec	
SUDAM	I5	51-55	SUDA SEGMENT NUMBER		NUMBER OF PIECES INTO WHICH PATH WILL BE DIVIDED
MILLM	I5	56-60	MILLINGTON SEGMENT NUMBER		NUMBER OF SEGMENTS INTO WHICH SUDA END SEGMENTS ARE DIVIDED
FACHNZ	F10.5	61-70	USER SUPPLIED HORIZONTAL NOISE FACTOR	km^{-1}	DEFAULTS TO 0.06



NAME LIST INPUT FOR COMEFF.

The format for the name list is "VARIABLE NAME-VALUE" and successive name list variables are separated by commas. The namelist is initiated with the term '&IINIT" beginning in column 2. The namelist is terminated by the term "&END" anywhere. Namelist variables may appear in any order. The namelist variables may span more than one card but must always begin in column 2.

NAMELIST VARIABLE	FORMAT	DESCRIPTION	VALUES
KSW1	I1	ISOTROPIC OR INPUT ANTENNA PATTERNS	≠ 0 ISOTROPIC = 0 INPUT PATTERNS
KSW2	I1	DOPPLER SHIFT	= 0 NO DOPPLER ≠ 1 DOPPLER OUTPUT
MNANGT	I2	LOWEST ANGLE FOR PATTERN SUPPLIED-TRANSMITTER	INTEGER VALUE IN DEGREES
MXANGT	I2	HIGHEST ANGLE FOR PATTERN SUPPLIED TRANS-MITTER	INTEGER VALUE IN DEGREES
MNANGR	I2	LOWEST ANGLE FOR PATTERN SUPPLIED-RECEIVER	INTEGER VALUE IN DEGREES
MXANGR	I2	HIGHEST ANGLE PATTERN SUPPLIED-RECEIVER	INTEGER VALUE IN DEGREES
NOFREQ	I2	NUMBER OF FREQ-UENCIES FOR WHICH ANTENNA PATTERNS VIGEN	INTEGER $\leq$ 8
PLREJ	F5.3	PATH LOSS LIMIT	RAY IGNORED IF PATH LOSS >PLREJ
P	F7.3	POWER DENSITY	WATTS/Hz DEFAULT=3.33
NEWANT	I2	NEW ANTENNA PATTERN	≠ 0 USE PREVIOUS ANTENNA PATTERN = 0 INPUT NEW PATTERN
BAUD	F7.3	SIGNALLING ELEMENT DURATION	DEFAULT = 10msec

Example of NAMELIST INPUT:

&IINIT KSW=0, KSW2=1, MXANGT=40, MNANGT=-40 MXANGR=40, MNANGR=-40 P=10, NOFREQ=2, PLREJ=200, NEWANT=0 & END

PRNT CONTROL CARD

This parameter controls printing of input antenna patterns.

NAME	FORMAT	COLUMNS	VALUES
		1-4	"PRNT"
VBL	I1	9	a 1 in column 9 causes every tenth angle to be printed
VBL	I1	10	a 1 in column 10 causes every angle to be printed.

FREQUENCY INPUT CARD

This card describes the frequencies for which antenna pattern data is to be input. This card is similar to the original NUCOM II card except the fields are compressed.

NAME	FORMAT	COLUMNS	DESCRIPTION	COMMENTS
TABLFR(1)	F5.1	1-6	FIRST FREQUENCY	MHz
TABLFR(2)	F5.1	6-10	2nd FREQUENCY	MHz
TABLFR(3)	F5.1	11-15	3rd FREQUENCY	MHz
TABLFR(4)	F5.1	16-20	4th FREQUENCY	MHz
TABLFR(5)	F5.1	21-25	5th FREQUENCY	MHz
TABLFR(6)	F5.1	26-30	6th FREQUENCY	MHz
TABLFR(7)	F5.1	31-35	7th FREQUENCY	MHz
TABLFR(8)	F5.1	36-40	8th FREQUENCY	MHz

ANTENNA PATTERN INPUT

Each antenna pattern card includes an integer angle and one to eight values of power gain relative to isotropic as specified in the namelist variable NOFREQ. Pattern values must start with MNANGT for transmitter and MNANGR for receiver patterns and end with MXANGT for transmitter and MXANGR for receiver patterns. Transmitter patterns are given first and for each angle specified the first card corresponds to vertical polarization and the second card to horizontal polarization. The values of MNANGR and MNANGT, MXANGR and MXANGT need not be the same; this allows use of small pattern decks for air-to-air and air-to-ground links when no ionospheric rays are present.

Antenna Gain Pattern (MXANGT-MNANGT+1 cards)

NAME	FORMAT	COLUMN	DESCRIPTION	COMMENT
IANG	I5	1-5	ANGLE	in degrees
TABL1(1)	F5.1	6-10	antenna gains for vertical polarization for NOFREQ values of frequency	
TABL1(2)	F5.1	11-15		
TABL1(3)	F5.1	16-20		
TABL1(4)	F5.1	21-26		
TABL1(5)	F5.1	26-30		
TABL1(6)	F5.1	31-35		
TABL1(7)	F5.1	36-40		
TABL1(8)	F5.1	41-45		

A second card with identical format gives the horizontal component values. Examples of complete pattern decks will be found in APPENDIX C.

DISTRIBUTION LIST

DEPARTMENT OF DEFENSE

Director
Command Control Technical Center
ATTN: C-650, G. C. Jones

Defense Communication Engineer Center
ATTN: R830
ATTN: R124C

Defense Documentation Center
Cameron Station
12 cy ATTN: TC

Director
Defense Intelligence Agency
ATTN: DT-1B

Director
Defense Nuclear Agency
ATTN: TISI, Archives
ATTN: STVL
3 cy ATTN: TITL, Tech. Library
ATTN: DDST
3 cy ATTN: RAAE

Dir. of Defense Rsch. & Engineering
Department of Defense
ATTN: S&SS (OS)

Commander
Field Command
Defense Nuclear Agency
ATTN: FCPR

Director
Interservice Nuclear Weapons School
ATTN: Document Control

Chief
Livermore Division, Field Command, DNA
Lawrence Livermore Laboratory
ATTN: FCPRL

Director
National Security Agency
ATTN: John Skillman, R52

DEPARTMENT OF THE ARMY

Commander/Director
Atmospheric Sciences Laboratory
US Army Electronics Command
ATTN: DRSEL-BL-SY-S, F. E. Niles

Commander
Harry Diamond Laboratories
ATTN: DRXDO-TI, Mildred H. Weiner
ATTN: DRXDO-NP, Francis N. Wimenitz

Director
TRASANA
ATTN: TCC/F. Payan, Jr.

Commander
US Army Comm.-Elec. Engrg. Instal. Agy.
ATTN: EED-PED, George Lane

DEPARTMENT OF THE ARMY (Continued)

Commander
US Army Electronics Command
ATTN: DRSEL-PL-ENV, Hans A. Bomke

Commander
US Army Foreign Science & Tech. Center
ATTN: P. A. Crowley

Commander
US Army Nuclear Agency
ATTN: MONA-WE, J. Berberet

DEPARTMENT OF THE NAVY

Chief of Naval Research
Navy Department
ATTN: Code 461

Commander
Naval Ocean Systems Center
ATTN: William F. Moler, Code 2200

Director
Naval Research Laboratory
ATTN: Code 5400, Hg. Comm. Dir., Bruce Wald
ATTN: Code 5460, Electromag. Prop. Branch

Officer-in-Charge
Naval Surface Weapons Center
ATTN: Code WA501, Navy Nuc. Prgms. Off.

DEPARTMENT OF THE AIR FORCE

Commander
ADC/DC
ATTN: DC, Mr. Long

AF Geophysics Laboratory, AFSC
ATTN: SUOL, Rsch. Lib.

AF Weapons Laboratory, AFSC
ATTN: DYC, Captain L. Wittwer
ATTN: SUL

AFTAC
ATTN: TN

Air Force Avionics Laboratory, AFSC
ATTN: AAD, Wade Hunt

Headquarters
Electronic Systems Division/YS
ATTN: YSEV

Commander
Foreign Technology Division, AFSC
ATTN: NICD, Library

Commander
Rome Air Development Center, AFSC
ATTN: EMTLD, Doc. Library

Commander in Chief
Strategic Air Command
ATTN: XPFS, Major Brian G. Stephan
ATTN: ADWATE, Captain Bruce Bauer

OTHER GOVERNMENT AGENCY

Departmentof Commerce
Office of Telecommunications
Institute for Telecom Science
ATTN: Library

DEPARTMENT OF DEFENSE CONTRACTORS

Analytical Systems Engineering Corp.
ATTN: Radio Sciences

The Boeing Company
ATTN: D. Murray

Computer Sciences Corporation
ATTN: John Spoor

ESL, Inc.
ATTN: James Marshall

General Electric Company
TEMPO-Center for Advanced Studies
10 cy ATTN: DASIAC
ATTN: B. Gambill

General Research Corporation
ATTN: John Ise, Jr.

GTE Sylvania, Inc.
Electronics Systems GRP-Eastern Div.
ATTN: Marshal Cross
ATTN: G. P. Nelson

Institute for Defense Analyses
ATTN: Ernest Bauer

Intl. Tel. & Telegraph Corporation
ATTN: Technical Library

Kaman Sciences Corporation
ATTN: Clifford D. DeJong

DEPARTMENT OF DEFENSE CONTRACTORS (Continued)

M.I.T. Lincoln Laboratory
ATTN: Lib. A-082 for David M. Towle

Mission Research Corporation
ATTN: Steven L. Gutsche
ATTN: Dave Sowle

The Mitre Corporation
ATTN: J. N. Freedman

Pacific-Sierra Research Corp.
ATTN: E. C. Field, Jr.

R & D Associates
ATTN: Bryan Gabbard

The Rand Corporation
ATTN: Cullen Crain

Science Applications, Inc.
ATTN: D. Sachs

Science Applications, Inc.
ATTN: B. Adams

Stanford Research Institute
ATTN: Walter Jaye
ATTN: Jacqueline Owen
ATTN: G. Smith

System Development Corporation
ATTN: E. G. Meyer

TRW Defense & Space Sys. Group
ATTN: R. K. Pleubuch, R1-2078